

JAPAN

EDICT OF GOVERNMENT

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JIS K 2301 (1992) (English): Fuel gases and natural gas -- Methods for chemical analysis and testing

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*The citizens of a nation must
honor the laws of the land.*

Fukuzawa Yukichi

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JAPANESE INDUSTRIAL STANDARD

Fuel gases and natural gas — Methods for chemical analysis and testing

JIS K 2301—1992

Translated and Published

by

Japanese Standards Association

In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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Fuel gases and natural gas - Methods for chemical analysis and testing K 2301-1992

1. Scope

This Japanese Industrial Standard specifies methods for chemical analysis of general constituent and special constituent and for testing of calorific value and specific gravity of fuel gases and natural gas. However, this Standard does not apply to liquefied petroleum gas⁽¹⁾ and liquefied natural gas.

Note (¹) The liquefied petroleum gases are in accordance with JIS K 2240.

Remarks 1. Applicable Standards to this Standard are shown in Attached Table 10.

2. Corresponding International Standards are shown in Attached Table 11.

3. Units and numerical values given in { } in this Standard are in accordance with the traditional units and are Standard values.

Further, these traditional units and numerical values become the information reference on and after 1995, 4, 1.

2. Definitions

For the purposes of this Standard, the following definitions apply:

- (1) fuel gas The "fuel gas" means gaseous substances generally used as fuel, such as town gas, coke oven gas, petroleum refinery off gas, oil cracked gas, producer gas, water gas, etc.
- (2) natural gas The "natural gas" means inflammable gas which has methane generated naturally as the principal constituent.
- (3) general constituent The "general constituent" means the principal constituents generally contained in the fuel gas and natural gas, such as methane and other gaseous hydrocarbons, hydrogen, carbon monoxide, carbon dioxide, oxygen, and nitrogen.
- (4) special constituent The "special constituent" means a constituent possibly contained in fuel gas and natural gas, such as total sulphurs, hydrogen sulfide, ammonia, naphthalene, and water content, other than general constituents.

- (5) calorific value The "calorific value" means the calorific value evolved by the complete combustion of gas in air and is expressed by total calorific value per 1 m^3 of dry gas under standard conditions $\text{kJ/m}^3 \{ \text{kcal/m}^3 \}$.
- (6) specific gravity The "specific gravity" means the ratio of the mass of the gas to the mass of dry air of the same volume under the same specific conditions of temperature and pressure near the ordinary temperature and ordinary pressure.
- (7) standard condition The "standard condition" means the condition of gas at a temperature of 0°C under the pressure of 101.32 kPa $\{760 \text{ mmHg}\}$.
- (8) sample gas The "sample gas" means the gas taken out for chemical analysis or testing.

3. Common items

Common items concerning chemical analysis shall, as a rule, be in accordance with the provisions of JIS K 0050, concerning handling of standard reagent, of JIS K 8005, concerning absorptiometry, of JIS K 0115, and concerning gas chromatography, of JIS K 0114.

4. Sampling of gas

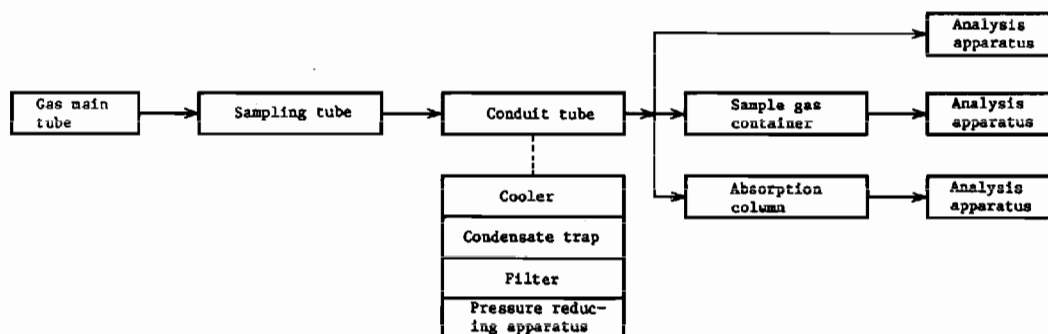
4.1 Sample gas The sample gas shall represent the original gas to be analyzed or tested.

4.2 Sampling position A sample of gas shall be taken from the position of flow where the concentration of constituent is generally even in cross-section and shall avoid the position adjacent to the juncture of the flow.

4.3 Sampling apparatus

4.3.1 The sampling apparatus shall be arranged as shown in Fig. 1 in accordance with the applicable methods for analysis and testing, and be operated in compliance with the procedures specified in the following items according to the condition of the sample gas.

Fig. 1. Example of arrangement of gas sampling apparatus



- (1) A suitable condensate trap shall be provided intermediately in the conduit tube where there is the possibility of moisture in the sample gas being condensated when analyzing the general constituents and measuring the calorific value and specific gravity.
- (2) The sampling tube and conduit tube shall be thermally insulated or heated by suitable means where there is the possibility of moisture or any oily content in the sample gas being condensated and giving the adverse effect to the result of analysis when analyzing the special constituent. If, it is difficult to provide a suitable thermal insulation or heating means and the condensate is separated through the condensate trap in accordance with the procedure specified in (1), the procedure for the analysis of the condensate and the subsequent correction of the analytical results shall be taken.
- (3) If the sample of gas contains tars or dusts, a suitable filter shall be provided intermediately in the sampling tube or conduit tube.
- (4) A suitable cooler shall be provided intermediately in the conduit tube when the sample of gas is taken from a hot source.
- (5) In case the sample of gas is taken from a source under high pressure, a suitable pressure-reducing means shall be provided to prevent moisture or partial constituents from being condensated due to adiabatic expansion when rapidly cooled, and for the purpose of ensuring safe operation.

4.3.2 The material qualities for the sampling tube and conduit tube including cooler, condensate trap, filter, pressure-reducing means which are to be connected as required, and for the several valves and gaskets shall satisfy the following requirements:

- (1) No chemical reaction or adsorption may cause an adverse effect on the analytical and testing results.
- (2) No constituent may cause corrosion.
- (3) Mechanical strength is sufficient for the temperature, pressure, and flow rate of the gas.

4.3.3 The sample gas container and absorption means shall be those specified in paragraphs 4.4 and 6.2 to 6.6.

4.4 Sampling method

4.4.1 General matters General matters for sampling method of sample gas shall be as follows:

- (1) Corresponding to the items for analysis or test, directly take the sample gas or take by introducing the sample gas into absorption apparatus or sample gas container.

- (2) As a preparatory procedure, the sampling tube, conduit tube, cooler, condensate trap, filter, pressure-reducing apparatus, and valves shall be displaced with a sample gas up to just in front of the sampling container and the absorption apparatus.
- (3) The flow rate and volume of the sample gas shall be in accordance with the provisions specified in the respective methods for analysis and testing.
- (4) In the case where the specified flow rate or the volume of sample cannot be obtained due to a lower pressure of the sample gas, a suitable suction pump or booster pump shall be used.
- (5) In the case where the sample gas is taken in a sample gas container, because depending upon the sample gas container the adsorption of gas components into apparatus wall, grease, etc., film permeation, absorption into sealing liquid, etc. are caused, in order to prevent composition change, without allowing to stand for a long time carry out the analysis or test.

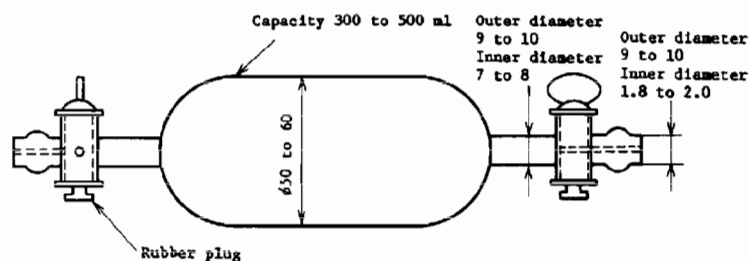
4.4.2 Sampling of gas for analysis of general constituents

The sampling of gas shall be performed according to either of the following methods:

- (1) Introduce the sample gas through sampling tube and conduit tube directly into gas chromatograph.
- (2) Take into the sample gas container. In this case, corresponding to the components of sample gas and condition of sample gas, use either of the following methods.
 - (a) Flowing or vacuum method A sample of gas is taken either by flowing the gas through the sampling bottle as shown in Fig. 2 with a volume at least ten times the capacity of the bottle, or by introducing the gas into the sampling bottle which is preparatorily kept at a vacuum by means of a vacuum pump. A slight amount of water-soluble grease, which does not absorb hydrocarbons, is applied to the cock provided at the sampling bottle.

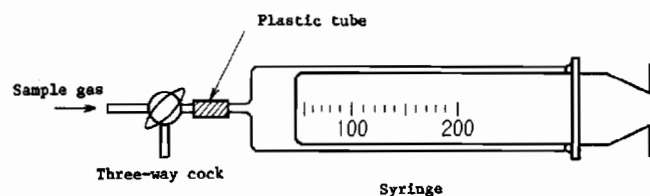
Fig. 2. Gas sampling bottle (An example)

Unit: mm



- (b) Syringe method A sample of gas is taken by introducing into the syringe type sampling apparatus as shown in Fig. 3 by withdrawing the inner cylinder. A slight amount of water-soluble grease as specified in the above (a) shall be applied to the ground root of the syringe.

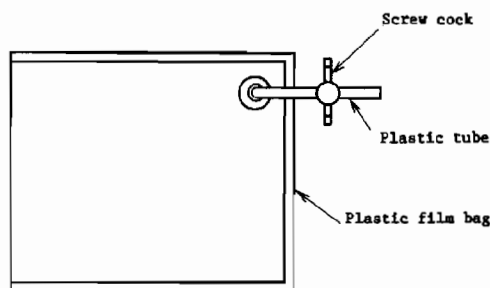
Fig. 3. Syringe type sampling apparatus (An example)



- (c) Gas collecting bag method A sample of gas is taken by introducing the gas into the gas collecting bag with a capacity of 1 l or more as shown in Fig. 4. The gas collecting bag is fabricated of polyester or fluorine resin-based plastic film which does not absorb or adsorb the gaseous constituents and is impermeable thereto⁽²⁾.

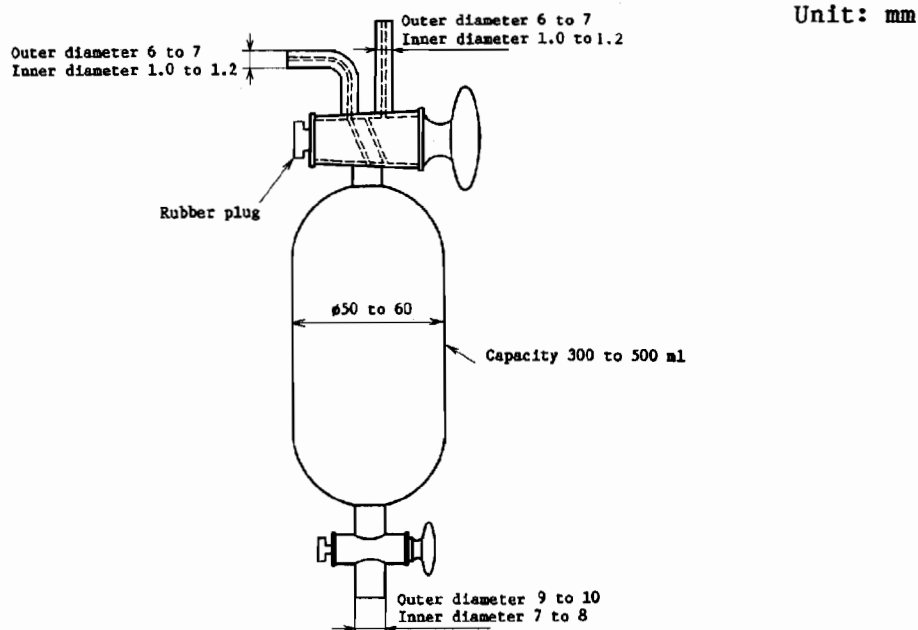
Note ⁽²⁾ This method, in the case where the sample gas must be preserved for a long time, is not applicable.

Fig. 4. Gas collecting bag (An example)



Remarks: According to the sample gas, the sealing liquid displacement method may be used. Fill the sealing liquid into the sampling bottle shown in Fig. 5, and while drawing out the sealing liquid, displace to the sample gas and take out. At this time, make the sealing liquid not to remain in the sampling bottle. As the sealing liquid, dissolve the sodium chloride 220 g specified in JIS K 8150 into water 1 l, make slightly acidic with hydrochloric acid, and after coloring by adding methyl orange indicator (1 g/100 ml) 1 to 2 ml, saturate with the gas of the same composition as that of sample gas to be used. In the case where the acidic gas such as carbon dioxide is contained in the sample gas, because according to the amount the error due to dissolution into the sealing liquid is generated, it should preferably be avoided.

Fig. 5. Gas sampling bottle (An example)



4.4.3 Gas sampling methods for analysis of special constituents One of the following methods shall be selected according to the constituents to be analyzed.

- (1) In the case of analyzing total sulphuric constituents, the sample gas shall be introduced from the conduit tube into the combustion apparatus directly through the gas meter.

In this case, the gas may be collected inside the gas collecting bag with a capacity of 20 to 50 l as shown in Fig. 4, and then the bag shall be installed on the measuring apparatus as shown in Fig. 6 for direct introduction into the combustion apparatus, provided that the gas contains a minimal amount of moisture or oil, and will not condensate itself at ordinary temperature.

- (2) For analysis of hydrogen sulphide, ammonia, and naphthalene, the gas shall, as a rule, be introduced from the conduit tube into the absorption apparatus that is specially specified for each method for analysis.
- (3) For analysis of moisture content, the gas shall be introduced into the moisture absorption apparatus or a dew-point meter through the conduit tube which has a dry interior surface, while taking care to prevent the gas from coming into contact with any moisture or oil. In this case, the conduit tube shall be made of material other than rubber or vinyl. Thick rubber tubing or silicone rubber tubing for vacuum shall be used for connection between the conduit tubes as well as the tube and the absorption apparatus.

4.4.4 Sampling of gas for measurement of calorific value The gas shall be directly introduced into the calorific value measurement apparatus through the conduit tube. Further, in the case where the calorific value is obtained according to calculation from the analysis results of general constituents by gas chromatograph, take out the sample gas according to 4.4.2.

4.4.5 Sampling of gas for measurement of specific gravity The gas shall be directly introduced into the hydrometer or specific gravity measurement apparatus. When the pycnometer method is employed, however, the gas may be collected into the sample gas collecting bag as shown in Fig. 4 and then introduced into the specific gravity measurement apparatus.

Further, in the case of obtaining the specific gravity according to the calculation from the analysis results of general constituents according to gas chromatograph, take out the sample gas according to 4.4.2.

If specific gravity is measured in accordance with the pycnometer method under the wet condition, the sample gas shall be introduced in accordance with the provisions of 4.4.3 (3).

4.5 Volume of sample gas The volume of the sample gas taken shall be measured by wet type gas meter, and at the same time shall be converted into the volume of dry gas at standard conditions by reading out atmospheric pressure, gas temperature, and gas pressure according to the following formula:

$$V_0 = V_1 \times \frac{273.15}{t_g + 273.15} \times \frac{1}{P_0} \times (B_0 + P - S) \times f_2$$

where, V_0 : volume of dry sample gas at standard conditions (l)

V_1 : volume of sample gas at the time of measurement (l)

t_g : temperature of sample gas at the time of measurement (°C)

P_0 : standard atmospheric pressure (101.32 kPa){760 mmHg}

B_0 : atmospheric pressure (kPa){ mmHg } at 0°C, and obtained according to the following formula.

$$B_0 = B - \alpha$$

where, B : indicated value by barometer (kPa){mmHg}

α : correcting value for conversion into atmospheric pressure, to be obtained from Attached Table 1 or 2 (kPa){mmHg}

P : gas pressure at gas meter (kPa){mmHg}.

In the case where the gas pressure is measured by (mmH₂O), if its value is taken as P_w , P is converted according to the following formula.

$$P = \frac{9.8}{1000} P_w (\text{kPa}) \quad [\text{ or } P = \frac{1}{13.6} P_w (\text{mmHg})]$$

S : pressure of saturated water vapor at t_g (kPa){mmHg} to be determined according to Attached Table 3 or 4.

f_2 : gas meter correction coefficient

Meanwhile, it is preferable to use Attached Table 5 or 6 to obtain the value $\frac{273.15}{t_g + 273.15} \times \frac{1}{P_0}$ in the formula.

Remarks: In the case where total sulphuric constituents are to be analyzed, the volume of the sample gas may be measured by a gas meter for the gas collecting bag.

An example of such gas meter is shown in Fig. 6. Operation and calculation of the volume of the sample gas shall be carried out in accordance with the following procedures:

(1) Operation

- (a) Open cock ①, and start up the pump ① to supply water into the metal measuring tank with a gauge.
- (b) Open cock ②, and start up the pump ② to transfer half the water in the metal water tank with internal marked line into the water storage tank.
- (c) Submerge the gas-collecting bag filled with the sample gas into the metal water tank with internal marked line, and hold the bag down with a keep plate.
- (d) Open cock ③, and start up the pump ③ to supply water into the water storage tank up to the level of water-mark line, while taking care to prevent formation of air bubbles between the gas collecting bag and the keep plate.
- (e) Open cock ⑤, and burn off a predetermined quantity of the sample gas in accordance with 6.2.1 (3). After burning is completed, open the cock ④ and fill the measuring water tank with water up to the level of the marked line.

- (2) Volume of sample gas Obtain the volume of sample gas at standard conditions from the reading of the scale of the measuring water tank according to the following formula:

$$V_0 = V_1 \times \frac{273.15}{t_g + 273.15} \times \frac{1}{P_0} \times (B_0 + P)$$

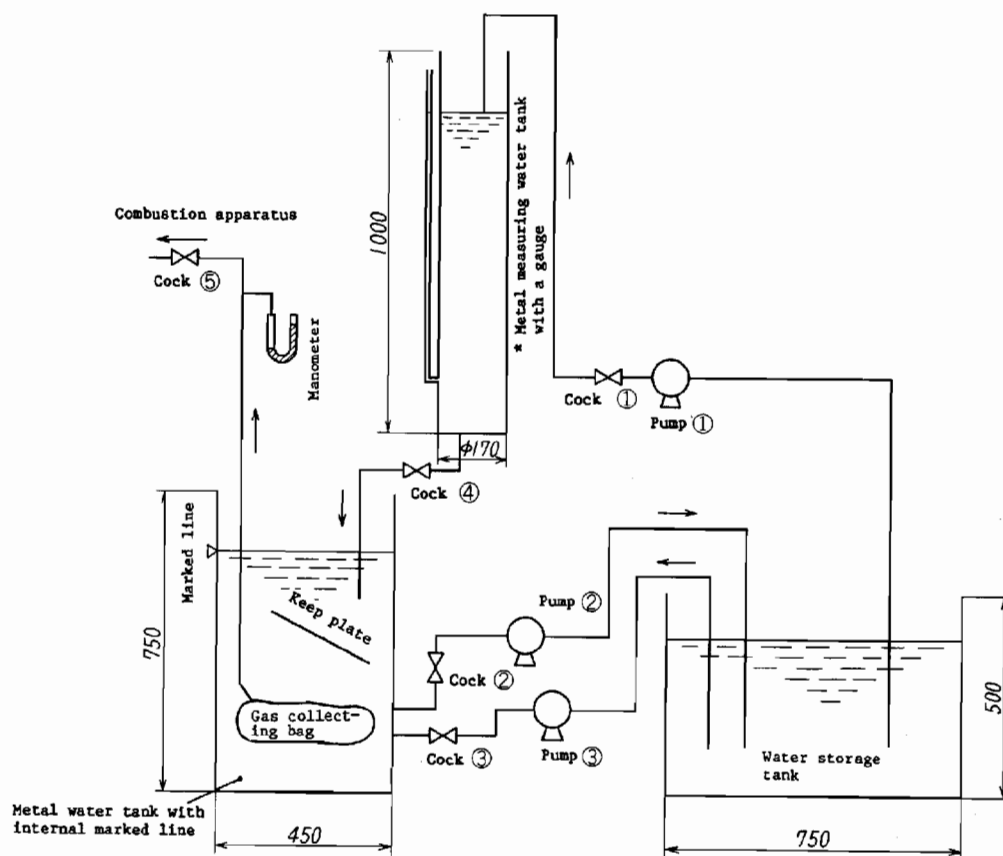
where, V_1 : volume of sample gas at the time of measurement (l)
(quantity of water reduced in the metal measuring water tank with a gauge)

t_g : temperature of sample gas at the time of measurement (°C)
(water temperature in the metal water tank with internal marked line)

P : pressure inside the gas collecting bag (kPa){mmHg}
(mercury column converted from the water column in a manometer)

Fig. 6. Gas measuring apparatus for gas collecting bag (An example)

Unit: mm



Note *: This is graduated every 1 cm, and preparatorily checked that 1 cm is equivalent to how many ml.

5. Methods for analysis of general constituents (Gas chromatography)

5.1 Summary This method is a means of separating each of the constituents in the sample gas through a combination of several types of columns by the use of a gas chromatograph that comprises a thermal conductivity type detector or hydrogen flame ionization detector and by subsequently comparing the peak area given on the chromatogram with the peak area of the mixed standard gas or pure gas under the same conditions, and thereby determining the content of each constituent after being corrected by a correction coefficient.

5.2 Constituents to be analyzed The analysis objective constituents of this method shall be as follows:

Hydrogen (H_2)	Isobutane ($i-C_4H_{10}$)
Oxygen (O_2)	Butane ($n-C_4H_{10}$)
Nitrogen (N_2)	Butene-series (C_4H_8)
Carbon Monoxide (CO)	1,3-butadiene (C_4H_6)
Carbon dioxide (CO_2)	Isopentane ($i-C_5H_{12}$)
Methane (CH_4)	Pentene ($n-C_5H_{12}$)
Ethane (C_2H_6)	Neopentane ($neo-C_5H_{12}$)
Ethylene (C_2H_4)	Pentene-series (C_5H_{10})
Propane (C_3H_8)	Cyclopentane ($cyclo-C_5H_{10}$)
Propylene (C_3H_6)	Hexane series (C_6H_{14})
	Benzene (C_6H_6)
	Toluene ($C_6H_5CH_3$)

Remarks 1. The butene-series shall include 1-butene, cis-2-butene, trans-2-butene, isobutene; the pentene-series shall include 1-pentene, cis-2-pentene, trans-2-pentene, 2-methyl-1-butene, 3-methyl-1-butene, 2-methyl-2-butene; and the hexane-series shall include hexane, isohexane, 3-methyl-pentane, 2,2-dimethylbutane, 2,3-dimethylbutane. However, as for natural gas, the hexane-series may include cyclopentane.

Further, the butene-series, pentene-series, and hexane-series indicate the results of quantitative analysis for each constituent, as a rule.

- When it is obvious that the sample gas is taken from the natural gas or petroleum gas, and does not contain any constituent such as hydrogen, carbon monoxide, or ethylene, such kind of constituents need not to be analyzed.
- As to the hydrocarbon series not less than C_6 which may be included in natural gas and the like, the constituents not less than C_6 are measured quantitatively in integration by applying back flushing and indicated as C_6+ .

5.3 Apparatus

5.3.1 Gas chromatograph⁽³⁾ The main components of the gas chromatograph shall satisfy the following requirements:

Note ⁽³⁾ The gas chromatograph, in order to avoid complexity such as column exchange, exchange of analysis conditions and to shorten the analysis time, plural stands for each column should preferably be set or plural flow route type gas chromatograph, be utilized.

(1) Detector

- (a) Thermal conductivity detector The thermal conductivity detector having the capability of obtaining about 1500 in S value (mV) by calculation according to the following formula, when the column (d), (e) or (f) shown in Table 1 are connected to the gas chromatograph and propane is introduced with helium as the carrier gas under the analytical conditions of Table 2.

In the case where the peak area is measured by data processor, obtain according to the following formula.

$$S = \frac{C \times F \times 10^{-3}}{60 \times Q}$$

where, C : peak area of propane by data processor ($\mu\text{V}\cdot\text{s}$)
 F : flow rate of carrier gas (ml/min)
 Q : quantity of propane introduced (ml)

In the case where the peak area is measured by peak width at half-height method, obtain according to the following formula.

$$S = \frac{D \times F \times A}{V \times Q}$$

where, D : recorder sensitivity per graduation width 1 cm on the record chart (mV/cm)
 F : flow rate of carrier gas (ml/min)
 A : peak area of propane by the peak width at half-height method (cm^2)
 V : feed speed of record chart (cm/min)
 Q : quantity of propane introduced (ml)

- (b) Hydrogen flame ionization detector The hydrogen flame ionization detector having the capability of obtaining about 0.001 in ρ value (coulomb/g) by calculation according to the following formula, when the column (g) shown in Table 1 is connected to the gas chromatograph and benzene specified in JIS K 8858 is introduced with nitrogen as the carrier gas under the analytical conditions of Table 2.

In the case where the peak area is measured by a data processor, obtain according to the following formula.

$$\rho = \frac{C \times 10^{-6}}{R \times W}$$

where, C : peak area of benzene by data processor ($\mu\text{V}\cdot\text{s}$)
 W : amount of benzene introduced (g)
 R : dynamic range of gas chromatograph (□)

In the case where the peak area is measured by peak width at half-height method, obtain according to the following formula.

$$\rho = \frac{D \times A \times 60 \times 10^{-3}}{V \times R \times W}$$

where, D : recorder sensitivity per graduation width 1 cm on the record chart (mV/cm)

V : feed speed of record chart (cm/min)

R : dynamic range of gas chromatograph (Ω)

A : peak area of benzene by the peak width at half-height method (cm²)

W : quantity of benzene introduced (g)

- (2) Sensitivity-change-over apparatus The sensitivity-change-over apparatus shall have a maximum attenuation ratio of not less than 500:1 and the attenuator accuracy, within 0.5 % at each step.
- (3) Column tank The column tank shall be capable of containing the column specified in 5.5, and be capable of maintaining the set temperature within a range of stability of $\pm 0.3^{\circ}\text{C}$.

Remarks: In the case of performing analysis by raising temperature, preliminarily confirm that the reproducibility of raising temperature programme is sufficient.

- (4) Flow rate control mechanism The flow rate adjusting valve for the carrier gas shall be capable of controlling stability the pressure within 1 % of the set pressure.

5.3.2 Gaseous sample introduction apparatus The gaseous sample introduction apparatus shall be designed to receive a sample gas measuring tube of 0.1 to 5 ml capacity, and be capable of satisfying the repeatability specified in 5.7 (3).

Proper selection shall be made for the volume of the sample gas measuring tube according to the concentration of the constituents to be analyzed and to the sensitivity of the detector.

5.3.3 Recorder The recorder shall be capable of the following performances, excepting where data processor specified in 5.3.4 is used.

- (1) Full scale 1 mV
- (2) Valid width of record chart 20 cm or more
- (3) Running time of pen 1 s or less per 99 % of full scale
- (4) Chart speed To be adjustable by 0.5 cm/min or more, as necessary.
- (5) Dead zone Within 0.15 % of full scale

5.3.4 Data processor A data processor is used to indicate the signal corresponding to the peak area of the constituent shown on the gas chromatogram in numerical value, and shall have the following performances:

- (1) Integrating sensitivity 1 count or more per 1 μ V.s
- (2) Accuracy Coefficient of variation for the ratio of peak area of nitrogen to that of oxygen (N_2/O_2) is within ± 0.5 % when the data processor is connected to the gas chromatograph and the air is repeatedly analyzed three times or more under the analysis conditions shown in Table 2.
- (3) Linearity Within ± 0.1 % to a measured input of 1 mV or more
- (4) Input voltage 1000 mV max.

5.4 Carrier gas, hydrogen gas, and ignition improving gas The carrier gas, hydrogen gas and ignition improving gas shall be as follows:

- (1) Carrier gas Use the helium and nitrogen having purity of 99.9 vol % or more. Instead of helium or nitrogen argon (purity of 99.9 vol % or more) may be used.
- (2) Hydrogen gas As to fuel gas of hydrogen flame ionization detector, use the hydrogen equivalent or superior to grade 4 (purity of 99.9 vol % or more) specified in JIS K 0512.
- (3) Ignition improving gas As to ignition improving gas of hydrogen flame ionization detector, use the air or oxygen demostured, refined of 0.196 MPa{2 kgf/cm²} or more in pressure.

5.5 Column The column shall be in accordance with the following:

- (1) Tube The tube used for the column is made of copper, stainless steel, glass, etc., with the internal diameter and length as shown in Table 1, and has end fittings firmly securable with the gas chromatograph.
- (2) Column packing materials Packing materials for the column shall have necessary, sufficient separating characteristics for the constituents being analyzed, as cited, for example, in Table 1.

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Table 1. Example of columns

Type of column		Packing material for column (An example)			Tube	
		Stationary-phase liquid	Type of carrier	Grain diameter of carrier μm	I.D. mm	Length m
a	Synthetic zeolite	Synthetic zeolite 13X-type (Na salt), or 5A-type (Ca salt)		177 to 250	3 to 5	1.5 to 3
b	Polymer beads	Porous polymer beads				2 to 4
c	Silica gel	Silica gel				1 to 2
d	Sebaco nitrile	Sebaco nitrile 25 %	Brown diatomaceous earth			8 to 10
e	n PS-DMS	n -propyl sulfone-dimethylsulfolane (75: 25) mixed solution 35 %	Brown diatomaceous earth	250 to 590	4 to 5	13 to 15
f	DOP	Diocetyl phthalate 25 %	Brown diatomaceous earth	177 to 250	3 to 5	5 to 7
g	PEG6000	Polyethylene glycol 25 %	Brown diatomaceous earth			1.5 to 3
h	Melt silica capillary	$\text{Al}_2\text{O}_3/\text{kCl}$			0.3	50

Informative reference: As to synthetic zeolite, there are molecular seave 13X, molecular seave 5A on the market.

Further for polymer beads, these is polapack Q on the market.

- (3) Packing method Using glass cotton, lightly plug up one end of the tube of which the internal surface has been thoroughly washed and dried, and then let each small amount of packing material flow from the other end of tube while vibrating the tube or sucking until the tube is evenly and consistently packed with no voids remaining. Finally plug up the other end lightly with glass cotton.
- (4) Prior heating of column Connect the column to the gas chromatograph at a predetermined position, and heat up the column while flowing the carrier gas and adjusting the temperature of the column tank so that it rises higher than the working temperature (but not higher than the maximum using temperature) until the remaining solvents and the like, are removed. In this case, one end of the detector's side of column is not be connected to the detector.

- (5) Combination of column It is necessary to use several type columns in combination for analysis of all compositions.

Examples of combinations of columns and analytical conditions are shown in Table 2, but if the separating elution of all constituents of sample gas is confirmed, it may be analyzed under other column combination and analysis conditions.

Table 2. Examples of combination of columns and analytical conditions

Combination of columns	Type of column	Constituents to be analysed	Analytical conditions			Type of standard gas	
			Tank temperature °C	Carrier gas	Flow rate ml/min	Pure gas	Mixed standard gas
A	Synthetic zeolite	H ₂	Ordinary temperature to 70	N ₂	30 to 60	H ₂	Use 5.6 (1),
	Synthetic zeolite	O ₂ , N ₂ , CH ₄ , CO	Ordinary temperature to 70	He		N ₂ or CH ₄	
	αPS-DMS	C ₂ H ₄ , C ₂ H ₆ , CO ₂ , C ₃ to C ₅ constituents	Ordinary temperature to 40	He		C ₃ H ₈	
	PEG6000	C ₆ H ₆ , C ₆ H ₅ CH ₃	80 to 120	He		-	
B	Synthetic zeolite	H ₂	Ordinary temperature to 70	N ₂	30 to 60	H ₂	
	Synthetic zeolite	O ₂ , N ₂ , CH ₄ , CO	Ordinary temperature to 70	He		N ₂ or CH ₄	
	Polymer beads	C ₂ H ₄ , C ₂ H ₆ , CO ₂	50 to 100	He		CO ₂	
	Sebacol nitrile	C ₃ to C ₆ constituents	Ordinary temperature to 60	He		C ₃ H ₈	
C	Synthetic zeolite	O ₂ , N ₂ , CH ₄	Ordinary temperature to 70	He	30 to 60	CH ₄	
	Silica gel	C ₂ H ₆ , CO ₂	50 to 70	He		CO ₂	
	DOP	C ₃ to C ₆ constituents	50 to 70	He		C ₃ H ₈	
D	Synthetic zeolite	H ₂	Ordinary temperature to 70	N ₂	30 to 60	H ₂	
	Synthetic zeolite	O ₂ , N ₂ , CH ₄ , CO	Ordinary temperature to 70	He		N ₂ or CH ₄	
	Polymer beads	C ₂ H ₄ , C ₂ H ₆ , CO ₂	50 to 100	He		CO ₂	
	Melt silica capillary	C ₃ to C ₆ constituents, C ₆ H ₆ , C ₆ H ₅ CH ₃	100 → 200 raising temperature	He	2 to 3	C ₃ H ₈	

5.6 Standard gas The standard gas to be referred to in the analysis of the sample gas shall be as follows.

- (1) Mixed standard gas Use the mixed gas of known concentration resembling the composition of sample gas.

Remarks 1. The mixed standard gas should preferably be contained with all constituents contained in sample gas to be analyzed, but relating to the constituent which is difficult to be filled in the high pressure container integrally such as oxygen, a certain type non-saturated hydrocarbon, high boiling point hydrocarbon, etc., use it by dividing into plural mixed standard gas. In case where even in this method it is not suitable, omit the containing, and calculate the omitted constituent by using the peak area value of other constituent contained in mixed standard gas, correction factor and concentration (Refer to 5.8).

2. The mixed standard gas of benzene or toluene difficult in filling in high-pressure container may be prepared according to the method specified in JIS K 0088, as appropriate.

(2) Pure gas Examples of pure gas to be used for analysis of sample gas are shown in the following:

Hydrogen Hydrogen of grade 3 specified in JIS K 0512 or more (purity 99.99 vol % or more)

Nitrogen Nitrogen of grade 2 specified in JIS K 1107 or more (purity 99.99 vol % or more)

Methane Purity 99.9 vol % or more

Carbon dioxide Purity 99.9 vol % or more

Propane Purity 99.5 vol % or more

Butane Purity 99.5 vol % or more

Remarks: The method to use the pure gas is easy in obtaining pure gas and is a simple, convenient method, but the correction factor may vary due to the apparatus, analysis conditions, etc., and therefore in order to perform analysis with accuracy the actually measured value should preferably be used for each gas chromatograph to be used.

5.7 Operation The operation shall be carried out according to the following procedures:

(1) Adjustment of gas chromatograph Prior to analysis, preliminarily adjust the gas chromatograph.

Informative reference: To be in accordance with handling manual of respective using apparatuses.

(2) Stabilization of gas chromatograph After setting the sensitivity exchange apparatus at the measuring conditions, start the recorder, and stabilize the gas chromatograph until the drift of base line becomes 1 % or less of recorder full scale in 10 min.

- (3) Confirmation of gas chromatograph for stability Introduce the standard gas into the sample gas measuring tube, alter the passage of the sample gas introduction apparatus to introduce the sample gas into the column so that the chromatogram can be recorded on the chart⁽⁴⁾. Repeat this procedure two times, and confirm that relating to the largest peak the difference in the peak height or in the count of the data processor between these two operations is within 1 % of the height or count⁽⁵⁾.

Notes ⁽⁴⁾ Alter the sensitivity change-over apparatus appropriately to ensure that the peak of constituent may be as high as possible within the range of maximum movement of the pen, excepting where the data processor is used.

⁽⁵⁾ If the difference is more than 1 %, suspect an imperfect displacement in the sample gas measuring tube, leakage of sample introduction apparatus, or an improperly operated sample gas introducing operation. These shall then be checked.

- (4) Introduction of standard gas Introduce the standard gas⁽⁶⁾ by using the same procedure as in (3), and record the chromatogram⁽⁴⁾.

Note ⁽⁶⁾ This operation may be made common with that defined in (3), but it is preferable to take this operation at least once at starting of analysis of one day or the analysis conditions are changed.

- (5) Introduction of sample gas After the sample gas container or conduit tube has been connected to the sample introduction apparatus, the sample gas has been flowed to the sample gas measuring tube and displacement has been achieved, alter the sample introduction passage to introduce the sample gas into the column, and then record the chromatogram on the chart⁽⁴⁾.
- (6) Identification of constituents The chromatogram obtained in (5) shall be submitted to identify the respective constituents at each peak by comparing with the sample of known constituent to know the retaining time, or with reference to Figs. 8 to 17.
- (7) Measurement of peak area The peak areas appearing in the chromatogram of the standard gas and of each analytical constituent to be analyzed are measured by the peak width at half height method or by data processor method. If it is analyzed by a capillary column, measure the peak area by the data processor method.
- (a) Data processor using method Take the count indicated by data processor as the peak area integral value.

- (b) Peak width at half-height method As shown in Fig. 7, the peak of chromatogram obtained is precisely measured by means of the gauge with an auxiliary rule up to 0.5 mm for height of peak and 0.1 mm for peak width at half height. The peak area (A) is calculated according to the following formula:

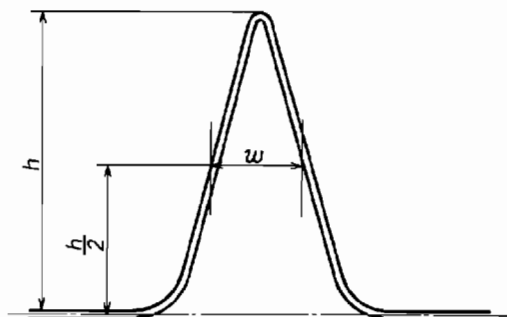
$$A = w \times h \times R (\text{mm}^2)$$

where, w : peak width at half height (mm)

h : height of peak (mm)

R : attenuation ratio of the sensitivity-change-over apparatus.

Fig. 7. Measuring method for peak area by peak width at half height method (In the case of symmetrical peak)



5.8 Calculation Calculation shall be made according to the following procedures:

- (1) Calculate the concentration of each constituent according to the following formula:

(1.1) In the case of using mixed standard gas

- (a) In the case of calculating constituent contained in mixed standard gas

$$C'_{vi} = \frac{A_i \times P_i}{A_s}$$

where, C'_{vi} : calculating concentration of constituent i in sample gas (vol %)

A_i : peak area of constituent i in sample gas (mm² or count)

A_s : peak area of constituent i in mixed standard gas (mm² or count)

P_i : concentration of constituent i in mixed standard gas (vol %)

- (b) In the case of calculating constituent not contained in mixed standard gas

$$C'_{vi} = \frac{A_i \times f_i \times C_{vs}}{A_s}$$

where, C'_{vi} : calculating concentration of constituent i in sample gas (vol %)

C_{vs} : concentration of constituent to be reference in mixed standard gas (vol %)

A_i : peak area of constituent i in sample gas (mm^2 or count)

A_s : peak area of constituent to be reference in mixed standard gas (mm^2 or count)

f_i : correction factor of constituent i to be constituent to be reference

However, because the correction factor (f_i) of constituent i may vary more or less due to apparatus and conditions, as a rule, the actually measured value is used. In the case free from interference specially, the correction factor of Table 3 or Table 4 may be used.

- (1.2) In the case of using pure gas

- (a) In the case of direct calculating of pure gas constituent

$$C'_{vi} = \frac{A_i \times P}{A_s}$$

where, C'_{vi} : calculating concentration of constituent i in sample gas (vol %)

A_i : peak area of constituent i in sample gas (mm^2 or count)

A_s : peak area of pure gas (mm^2 or count)

P : purity of pure gas (vol %)

- (b) In the case of calculating of constituent other than pure gas constituent

$$C'_{vi} = \frac{A_i \times f_i \times P}{A_s}$$

where, C'_{vi} : calculating concentration of constituent i in sample gas

A_i : peak area of constituent i in sample gas (mm^2 or count)

A_s : peak area of pure gas (mm^2 or count)

f_i : correction factor of constituent i to reference constituent

P : purity of pure gas (vol %)

However, because the correction factor (f_i) of constituent i may vary more or less due to apparatus and conditions, as a rule, the actually measured value is used. In the case free from interference specially, the correction factor of Table 3 or Table 4 may be used.

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Remarks: According to Remarks 3 to 5.2, in the case where the high-boiling point hydrocarbon not less than C_6 is determined as C_6^+ integrally by using back flushing operation, when the paraffine series are the main constituents, calculate with estimating as hexane and when the aromatic hydrocarbon series are main constituents, calculate with estimating as benzene.

- (2) Obtain the aggregated value of the calculating concentration of each constituent in (1), and when the value is within the range of 98.00 through 102.00 vol % (⁷), the analytical value for each constituent shall be calculated according to the following formula:

$$C_{vi} = \frac{C'_{vi}}{\sum C'_{vi}} \times 100$$

where, C_{vi} : analytical value of the constituent i in the sample gas (vol %)

C'_{vi} : calculating concentration of the constituent i in the sample gas (vol %)

$\sum C'_{vi}$: aggregated value of the calculating concentration of each constituent (vol %)

Note (⁷) If the aggregated value of the calculating concentration of each constituent deviates from the range of 98.00 through 102.00 vol %, suspect serious error in the adjustment of the apparatus, in the analytical operation, or in calculation, or the inclusion of constituents other than those being analyzed. A thorough check shall then be made.

Table 3. Correction factor for constituents in thermal conductivity type gas chromatograph (f_i)

Carrier gas			Nitrogen	Helium					
Standard gas				Hydrogen	Nitrogen	Methane	Carbon dioxide	Propane	Butane
Constituent to be analyzed									
1	Hydrogen	H ₂	1.00						
2	Oxygen	O ₂		1.05	0.90				
3	Nitrogen	N ₂		1.00	0.86				
4	Carbon monoxide	CO		1.00	0.86				
5	Carbon dioxide	CO ₂		0.88	0.75	1.00	1.35		
6	Methane	CH ₄		1.17	1.00		1.80		
7	Ethane	C ₂ H ₆				0.94	1.27		
8	Ethylene	C ₂ H ₄				1.00	1.35		
9	Propane	C ₃ H ₈				0.74	1.00		
10	Propylene	C ₃ H ₆				0.76	1.03		
11	Isobutane	<i>i</i> -C ₄ H ₁₀					0.79	1.04	
12	Butane	<i>n</i> -C ₄ H ₁₀					0.76	1.00	
13	1-Butene	1-C ₄ H ₈					0.80	1.05	
14	Trans-2-butene	<i>trans</i> -2-C ₄ H ₈					0.76	1.00	
15	Cis-2-butene	<i>cis</i> -2-C ₄ H ₈					0.75	0.99	
16	Iso-butene ⁽⁸⁾	<i>i</i> -C ₄ H ₈					0.79	1.04	
17	1,3-Butadiene	1,3-C ₄ H ₆					0.81	1.07	
18	Iso-pentane ⁽⁸⁾	<i>i</i> -C ₅ H ₁₂					0.65	0.86	
19	Pentane	<i>n</i> -C ₅ H ₁₂					0.62	0.82	
20	1-Pentene ⁽⁸⁾	1-C ₅ H ₁₀					0.63	0.83	
21	Cyclopentane	<i>cyclo</i> -C ₅ H ₁₀					0.67	0.88	
22	Iso-hexane	<i>i</i> -C ₆ H ₁₄					0.54	0.71	
23	Hexane ⁽⁸⁾	<i>n</i> -C ₆ H ₁₄					0.53	0.70	
24	Benzene	C ₆ H ₆					0.65	0.86	
25	Toluene	C ₆ H ₅ CH ₃					0.56	0.74	

Note (8) Iso-butene may represent butene-series; iso-pentane may represent neopentane; 1-pentene may represent pentene-series; hexane may represent hexane-series.

Table 4. Constituent correction factor in hydrogen flame ionization type gas chromatograph (f_i)

Carrier gas			Nitrogen	
Standard gas			Butane	Propane
Constituent to be analyzed				
1	Methane	CH ₄		3.2
2	Ethane	C ₂ H ₆		1.5
3	Ethylene	C ₂ H ₄		1.5
4	Propane	C ₃ H ₈		1.0
5	Propylene	C ₃ H ₆		1.05
6	Iso-butane	<i>i</i> -C ₄ H ₁₀	1.0	0.75
7	Butane	<i>n</i> -C ₄ H ₁₀	1.0	0.75
8	1-Butene	1-C ₄ H ₈	1.0	0.75
9	Trans-2-butene	<i>trans</i> -2-C ₄ H ₈	1.0	0.75
10	Cis-2-butene	<i>cis</i> -2-C ₄ H ₈	1.0	0.75
11	Iso-butene(⁹)	<i>i</i> -C ₄ H ₈	1.0	0.75
12	1,3-Butadiene	1,3-C ₄ H ₆	1.0	0.75
13	Iso-pentane(⁹)	<i>i</i> -C ₅ H ₁₂	0.77	0.58
14	Pentane	<i>n</i> -C ₅ H ₁₂	0.77	0.58
15	1-Pentene(⁹)	1-C ₅ H ₁₀	0.77	0.58
16	Cyclopentane	<i>cyclo</i> -C ₅ H ₁₀	0.80	0.60
17	Iso-hexane	<i>i</i> -C ₆ H ₁₄	0.63	0.47
18	Hexane(⁹)	<i>n</i> -C ₆ H ₁₄	0.63	0.47
19	Benzene	C ₆ H ₆	0.69	0.52
20	Toluene	C ₆ H ₅ CH ₃	0.61	0.45

Note ⁽⁹⁾ Iso-butene may represent butene-series; iso-pentane may represent neopentane; 1-pentene may represent pentene-series; hexane may represent hexane-series.

5.9 Expression of analysis results

- (1) The analysis values of respective constituents shall be expressed by rounding off to two places of decimals according to JIS Z 8401. If the aggregate does not become 100.00 vol %, increase or decrease the largest numerical value out of the constituent analysis values and make the aggregate coincident with 100.00 vol %.
- (2) The tolerance of analysis values when carried out twice successively by the same person by using the same apparatus on the same sample shall be as shown in Table 5⁽¹⁰⁾.

Note (¹⁰) In case where it is difficult to carry out the analysis twice on the same sample, by using the mixed standard gas resembling composition as that of sample gas, the confirming of accuracy may be carried out preliminarily.

Table 5. Tolerances for gas chromatograph analysis method

		Unit: vol%
Analysis value		Tolerance
Less than 1		0.03
1 min.	less than 5	0.05
5 min.	less than 25	0.15
25 min.		0.30

Fig. 8. Chromatogram on synthetic zeolite
 (Example 1) (Determination of hydrogen)

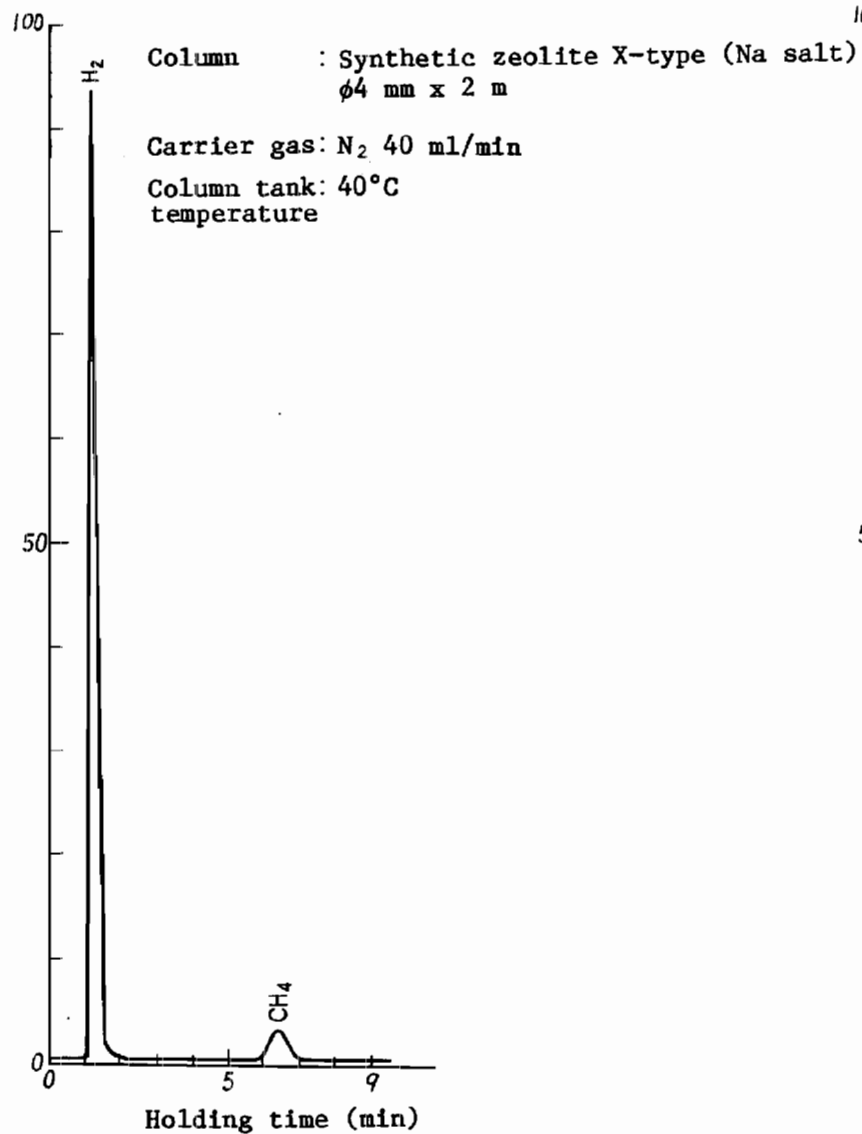
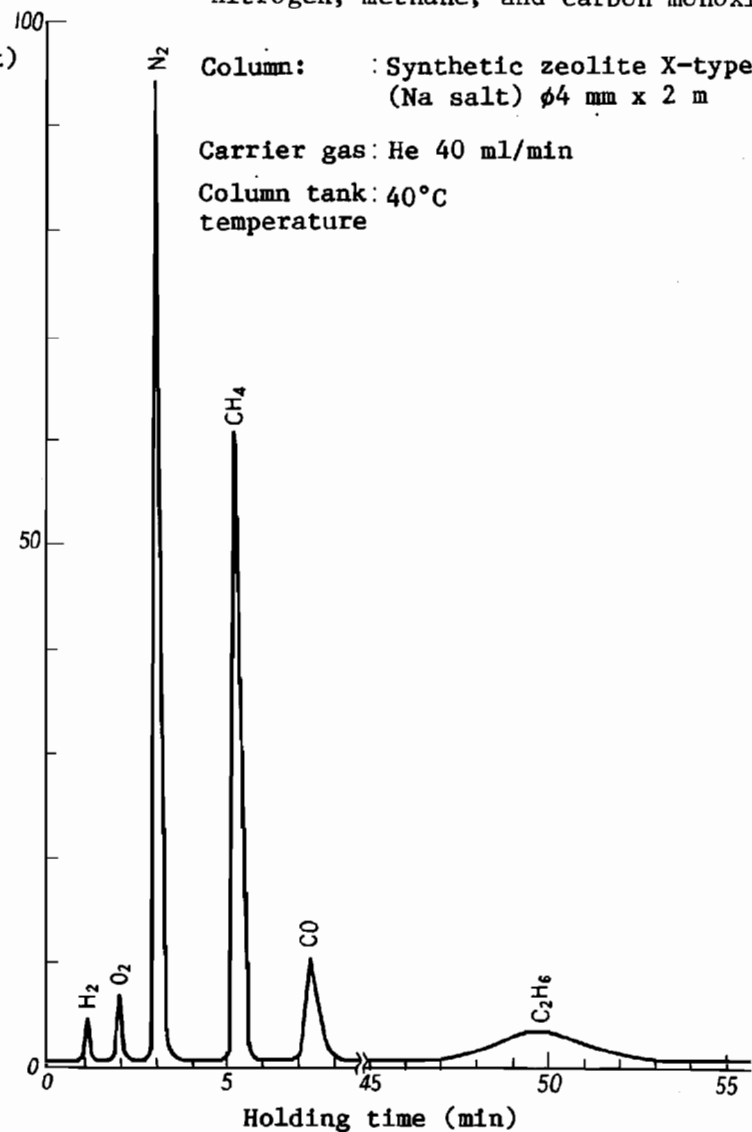


Fig. 9. Chromatogram on synthetic zeolite
 (Example 2) (Determination of oxygen,
 nitrogen, methane, and carbon monoxide)



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JIS K*2301 92 ■ 4933608 0504769 200 ■

Fig. 10. Chromatogram on polymer beads (Example)

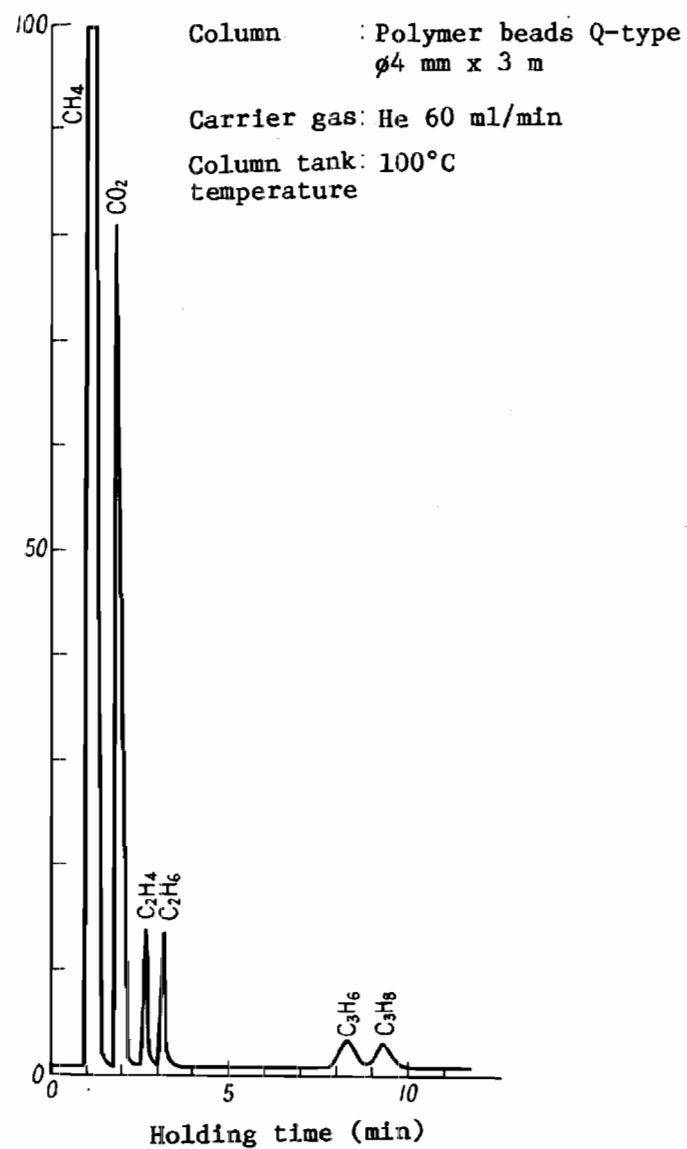


Fig. 11. Chromatogram on silica gel (Example)

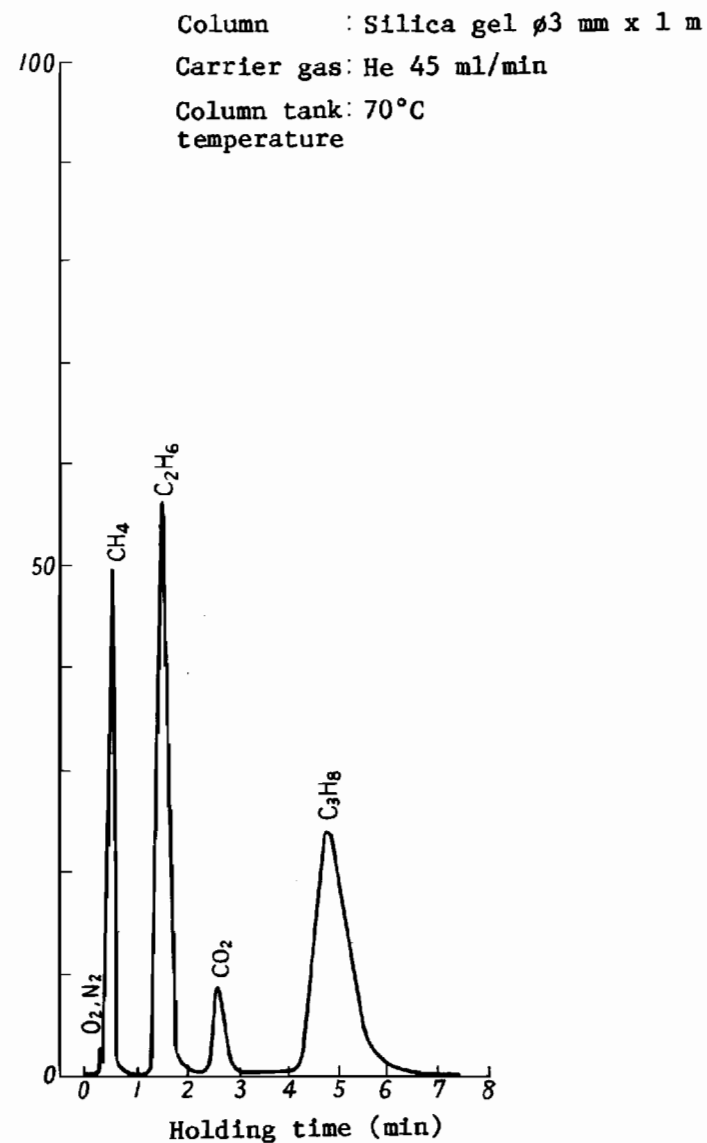


Fig. 12. Chromatogram on *n*PS-DMS (Example)

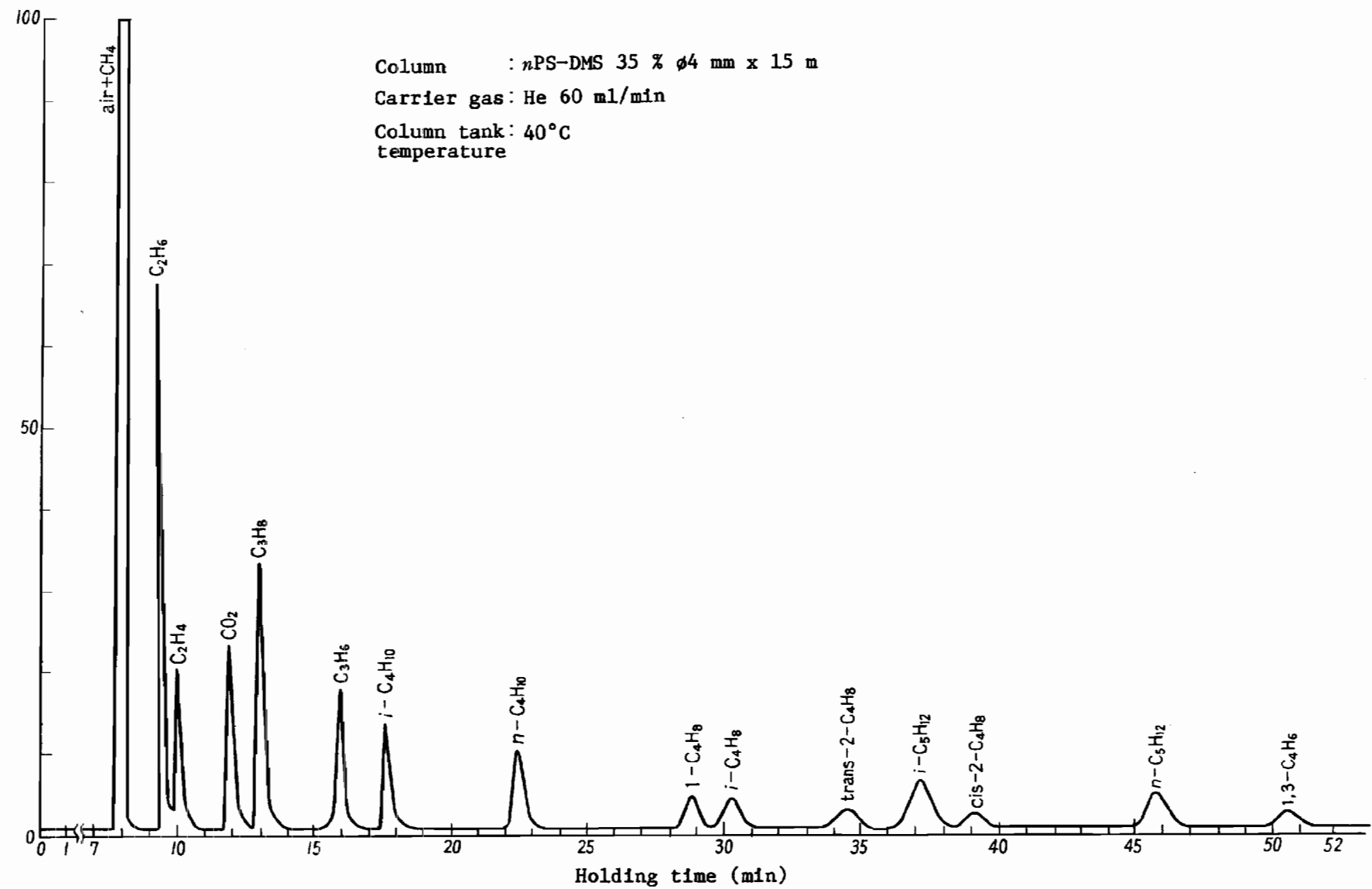
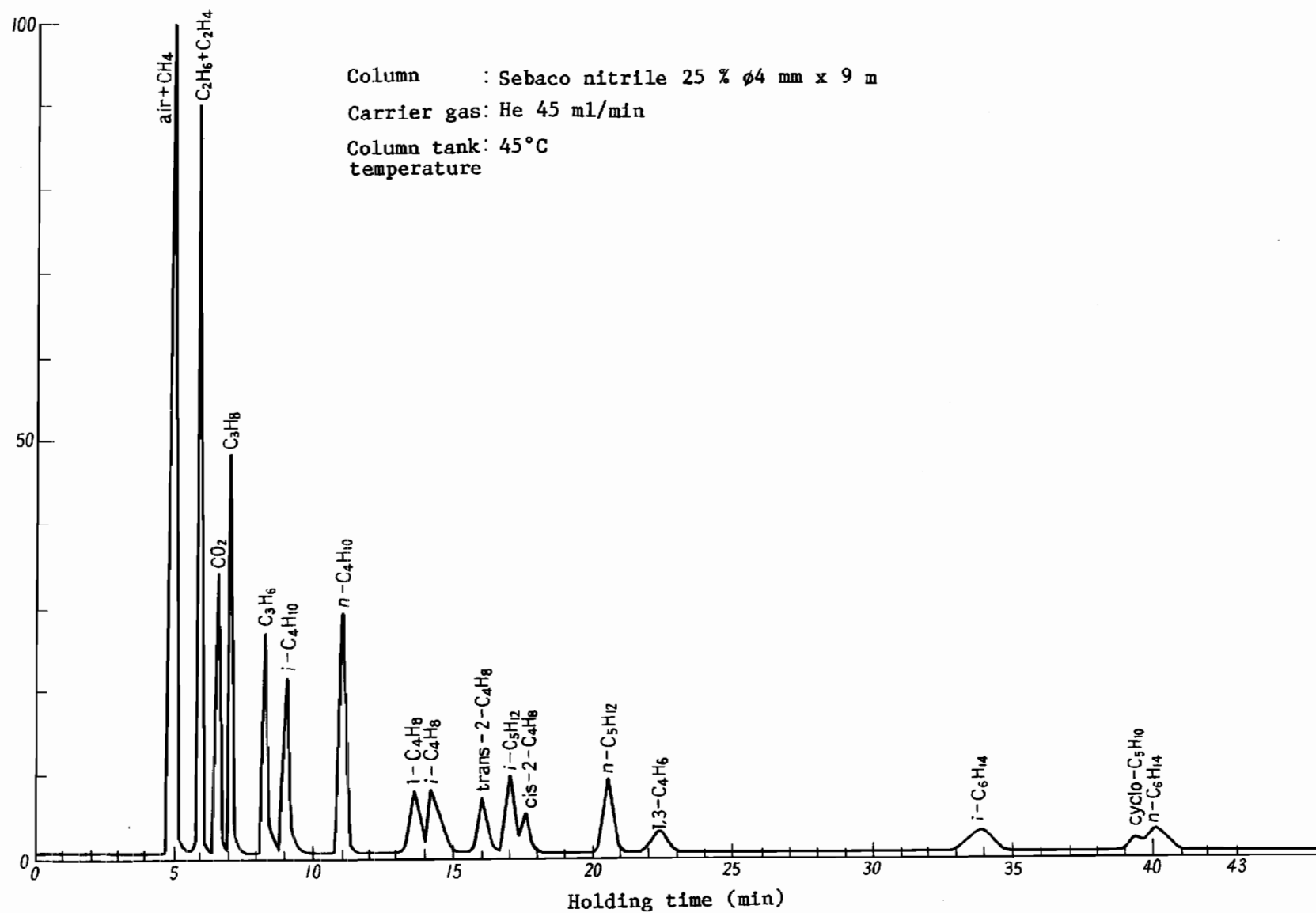


Fig. 13. Chromatogram on sebaco nitrile (Example)



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Fig. 14. Chromatogram on DOP (Example)

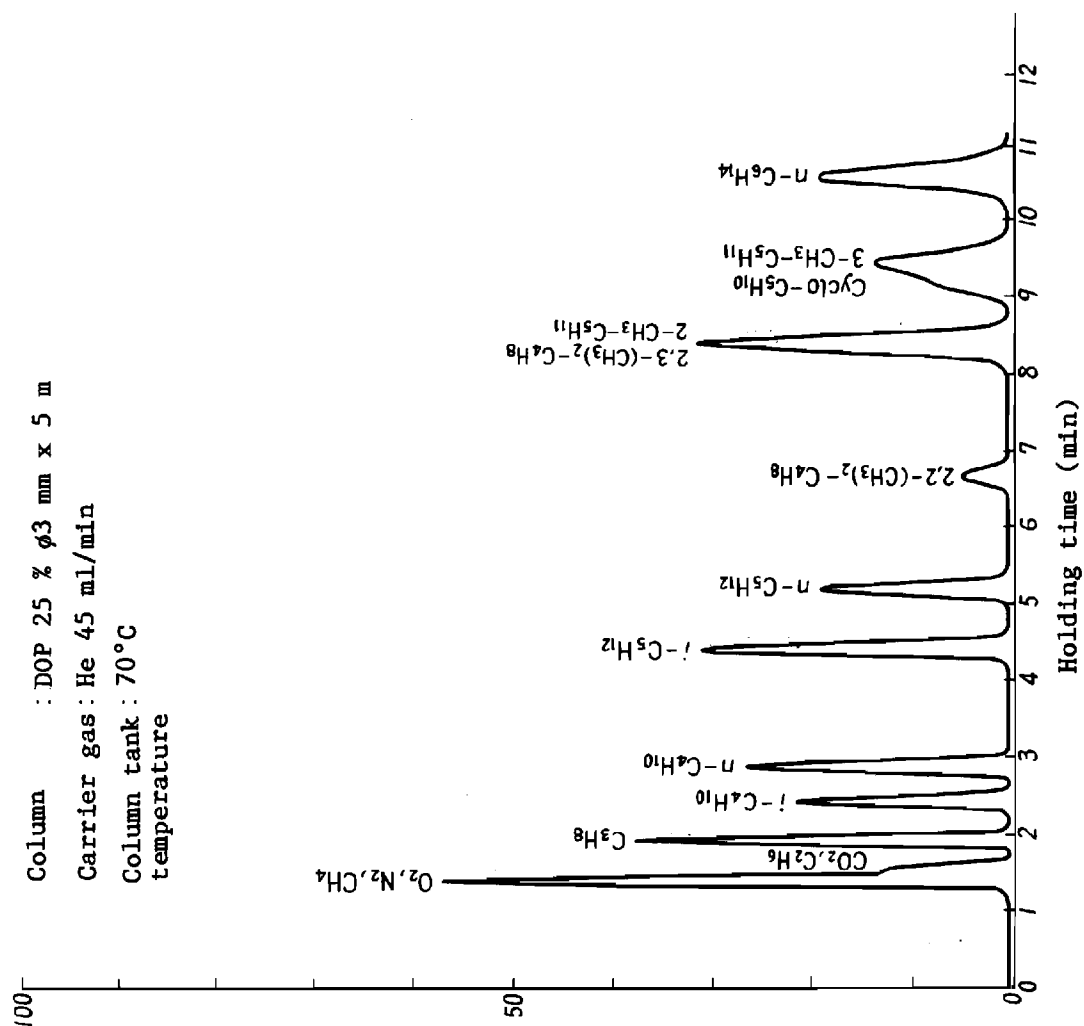


Fig. 15. Chromatogram on PEG6000 (Example)

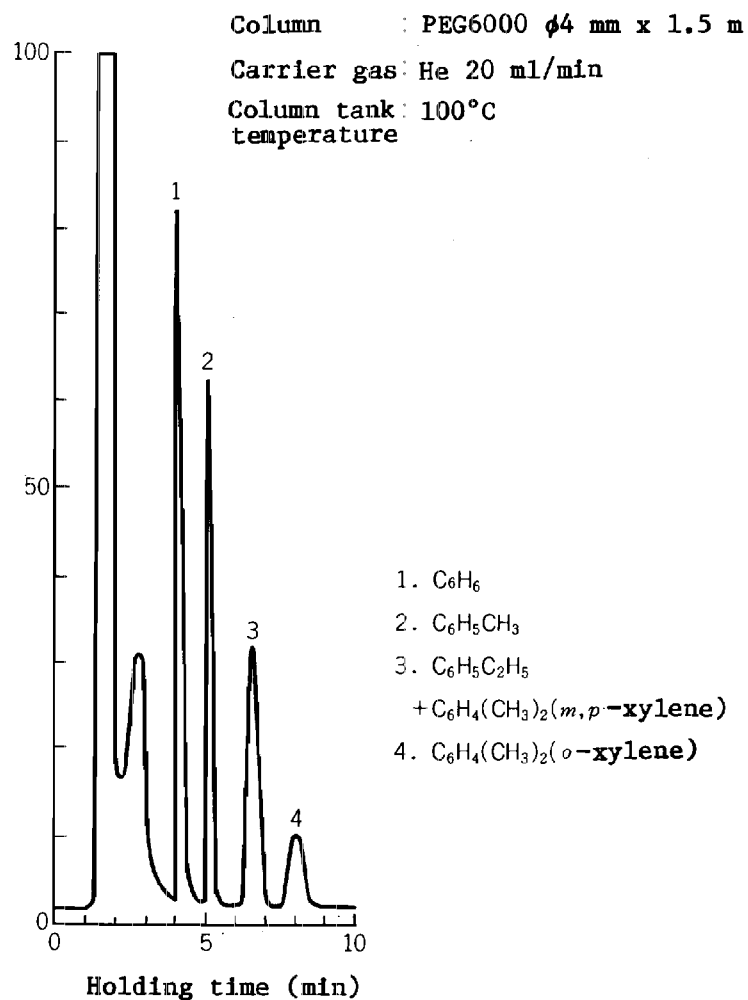


Fig. 16. Chromatogram on melt-silica capillary column (Example)

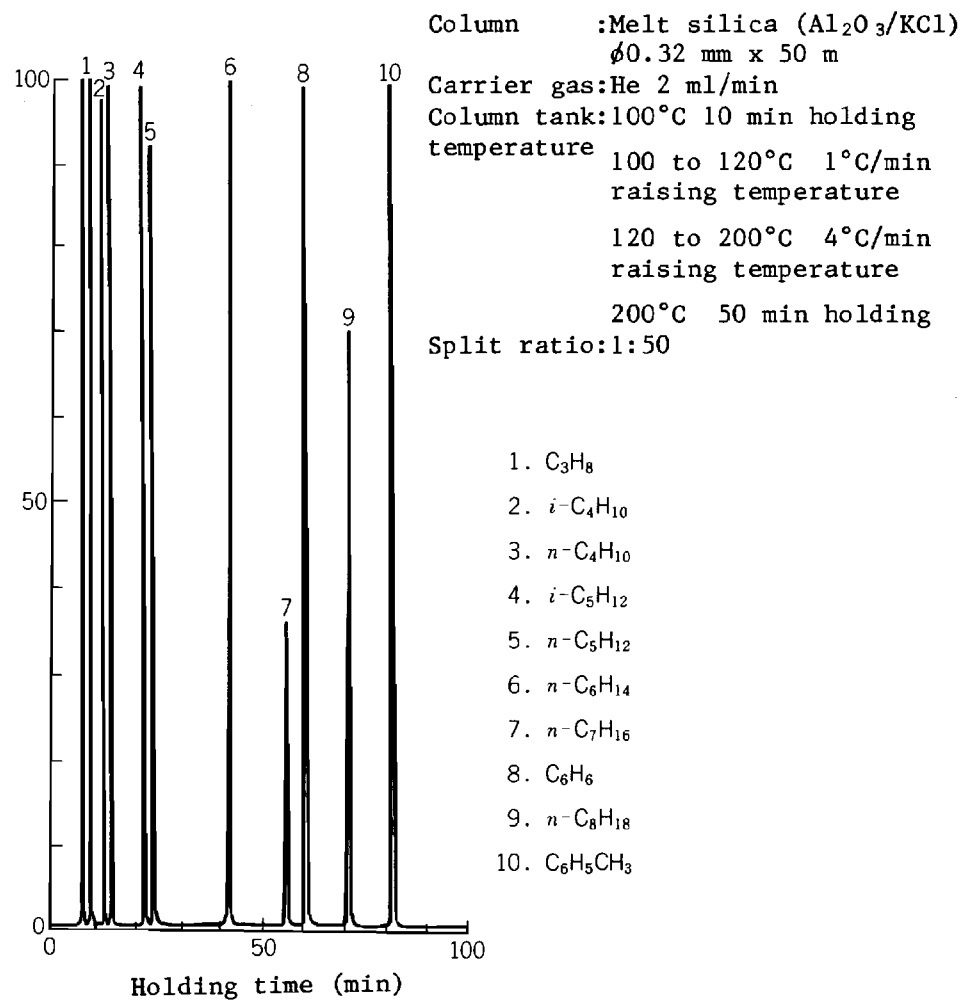
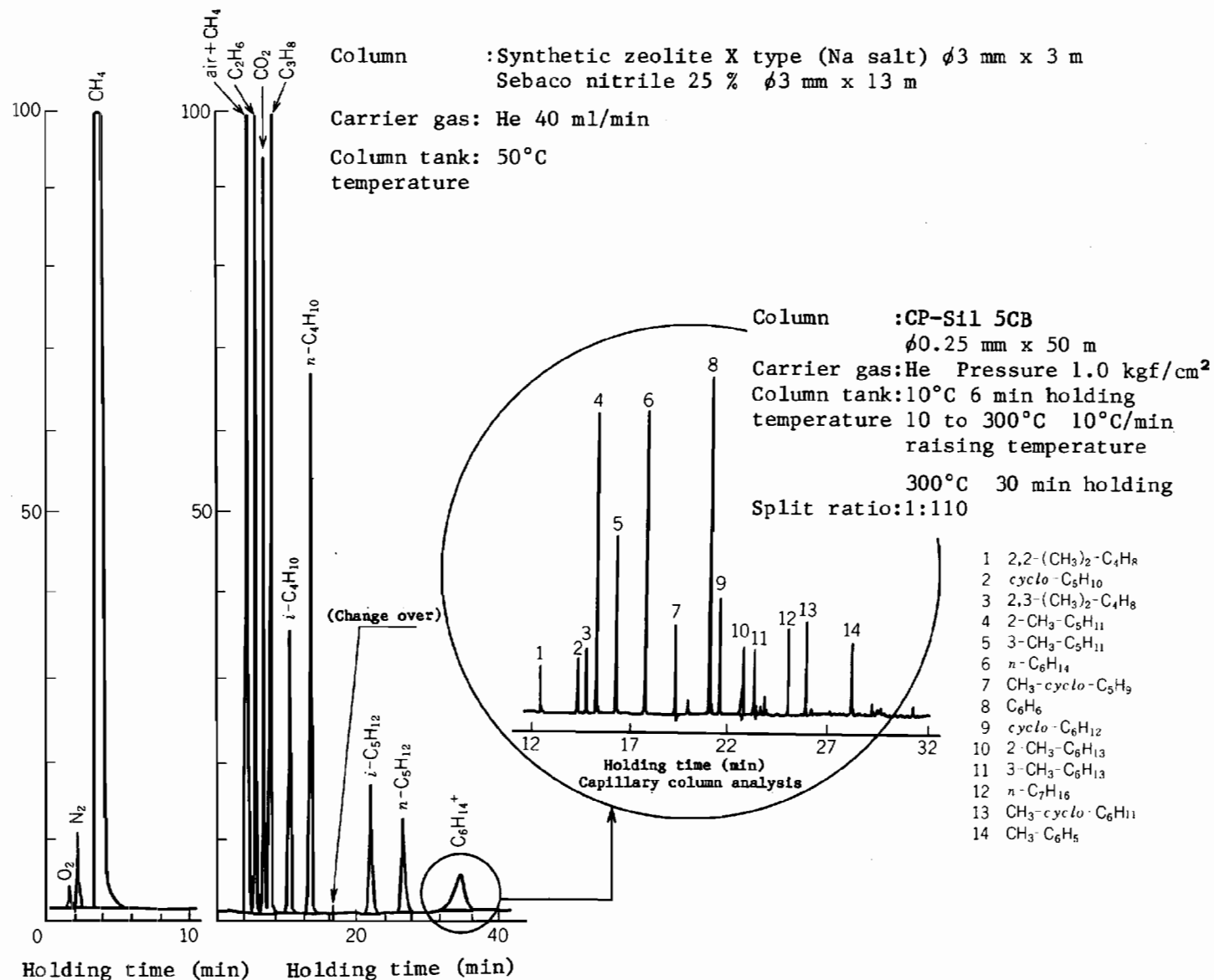


Fig. 17. Natural gas analysis used with back flushing (An example)



6. Analysis method for special constituent6.1 Division of special analysis constituents and analysis methods

Table 6. Division of analysis constituents and analysis methods

Analysis constituent	Analysis method
Total sulphur	Barium perchlorate precipitation titrimetric method Dimethyl sulphonazo. III absorptiometry
Hydrogen sulphide	Iodine titrimetric method Methylene blue absorptiometry Lead acetate test paper method
Ammonia	Neutralization titrimetric method Indophenol absorptiometry Silver nitrate - manganese nitrate test paper method
Naphthalene	Gas chromatography
Moisture content	Absorption weighing method Dew-point method

6.2 Analysis method of total sulphur6.2.1 Barium perchlorate precipitation titric method

(1) Summary Mix the sample gas with air or introduce into oxygen-hydrogen flame to burn, absorb the generated oxide of sulphur into hydrogen peroxide water, after making sulphuric acid, make pH about 6 with aqueous ammonia, add acetone, use dimethyl sulphonazo III as indicator and titrate with barium perchlorate solution. This method, in the case where sample gas of 100 l is taken, is capable of analyzing of gas not less than 0.01 g/m³ in total sulphur concentration.

(2) Reagents Reagents shall be as follows:

(2.1) Absorption liquid Hydrogen peroxide water (1+9)

This solution is preserved in a brown bottle.

(2.2) Aqueous ammonia (1+200)

(2.3) Potassium chloride solution Dissolve the potassium chloride 1 g specified in JIS K 8121 into water to make 100 ml.

- (2.4) Ethyl alcohol The ethyl alcohol specified in JIS K 8102.
- (2.5) Acetone The acetone specified in JIS K 8034.
- (2.6) Standard potassium sulphate solution (0.05 mgS/ml) Dry the pulverized potassium sulphate specified in JIS K 8962 at 105 to 110°C for 2.5 to 3 h, weigh out its 0.272 g, transfer to a beaker (200 ml) and dissolve in a small amount water. Transfer this to a measuring flask (1 l) with washing and add water up to the marked line.
- (2.7) 1/200 mol barium perchlorate standard solution⁽¹⁾ Dissolve barium perchlorate (trihydrate) 1.95 g specified in JIS K 9551 in water, and after adding 4 to 5 drops of perchloric acid (10 %), make 1 l with water. The standardization is in accordance with the following.

Take the standard potassium nitrate solution 10 ml with a transfer pipette into a conical beaker (200 ml), add water 15 ml, potassium chloride solution 1 ml, acetone 50 ml and dimethyl sulphonazo III solution 4 to 5 drops, and hereinafter operate similarly to (4.3).

Separately carry out the blank test by using water and calculate the factor according to the following formula.

$$f = \frac{0.05 \times 10}{0.160 \times (a - b)}$$

where, f : factor of 1/200 mol barium perchlorate standard solution

a : amount of 1/200 mol barium perchlorate standard solution required for initial titration (ml)

b : amount of 1/200 mol barium perchlorate standard solution required for blank test (ml)

Note ⁽¹⁾ Instead of 1/200 mol barium perchlorate standard solution, 1/200 mol barium chloride standard solution may be used. In this case, dissolve the barium chloride (dihydrate) 1.22 g specified in JIS K 8155 in water to make 1 l, and hereafter operate similarly as in the text.

- (2.8) Bromocresol green solution Dissolve bromocresol green 0.04 g specified in JIS K 8840 into ethyl alcohol (95) 20 ml specified in JIS K 8102, and add water to make 100 ml.
- (2.9) Dimethylsulphonazo III solution Dissolve dimethylsulphonazo III (disodium salt) 0.02 g in water 20 ml. Put this solution into a brown bottle and preserve in a cool, dark place.

- (3) Combustion of sample gas The sample gas shall be burned according to either one method of the following method A, method B or method C. The relation between the calorific value and combustion flow rate of sample gas in each combustion method shall be as given in Table 7.

The sample gas amount to be burned should preferably be such that the sulphur total amount to be absorbed becomes 1 to 8 mg.

Table 7. Relation between the calorific value and combustion flow rate of sample gas

Total calorific value of gas kJ/m ³ {kcal/m ³ }	Combustion flow rate l/h			
	10500 up to and excluding 21000 {2500 up to and excluding 5000}	21000 up to and excluding 42000 {5000 up to and excluding 10000}	42 000 up to and excluding 84000 {10000 up to and excluding 20000}	84000 up to and excluding 126000 {20000 up to and excluding 30000}
Combustion method				
Method A (General method)	20 to 10 (Nozzle mouth diameter 3 mm)	10 to 5 (Nozzle mouth diameter 2 mm)	5 to 2 (Nozzle mouth diameter 2 mm)	-
Method B (Rapid method)	100 min.	100 to 40	40 to 20	20 to 10
Method C (Acid-hydrogen flame heat combustion method)	300 min.	300 to 220	220 to 180	180 to 150

Remarks: In the case where the sample gas contains hydrogen sulphide and the volume is measured by using a wet type gas meter, arrange the hydrogen sulphide absorption apparatus shown in Fig. 24 or Fig. 26 in front of gas meter, burn the gas after collecting the hydrogen sulphide, determine the total sulphur, at the same time determine this collected hydrogen sulphide according to 6.3.1 or 6.3.2, after converting to the amount of total sulphur and add to the total sulphur determination value to correct.

(3.1) Method A (General method)

- (3.1.1) Apparatus An example of method A combustion apparatus is shown in Figs. 18 and 19. Preliminarily pass sufficiently the sample gas to saturate the water in the meter with sample gas.

Fig. 18. Method A combustion apparatus (An example)

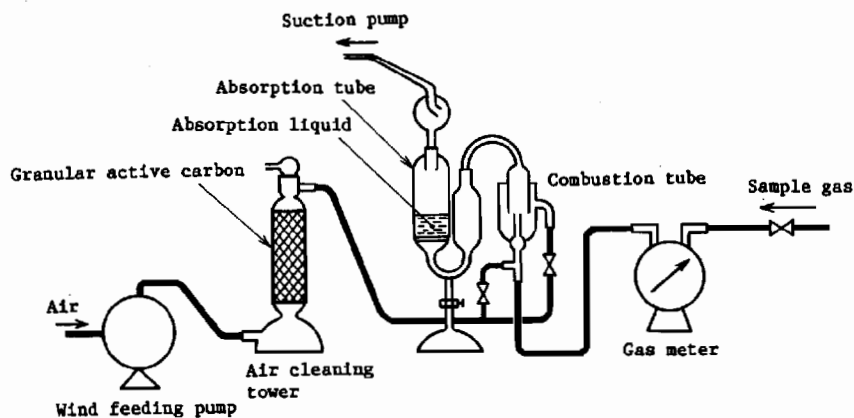
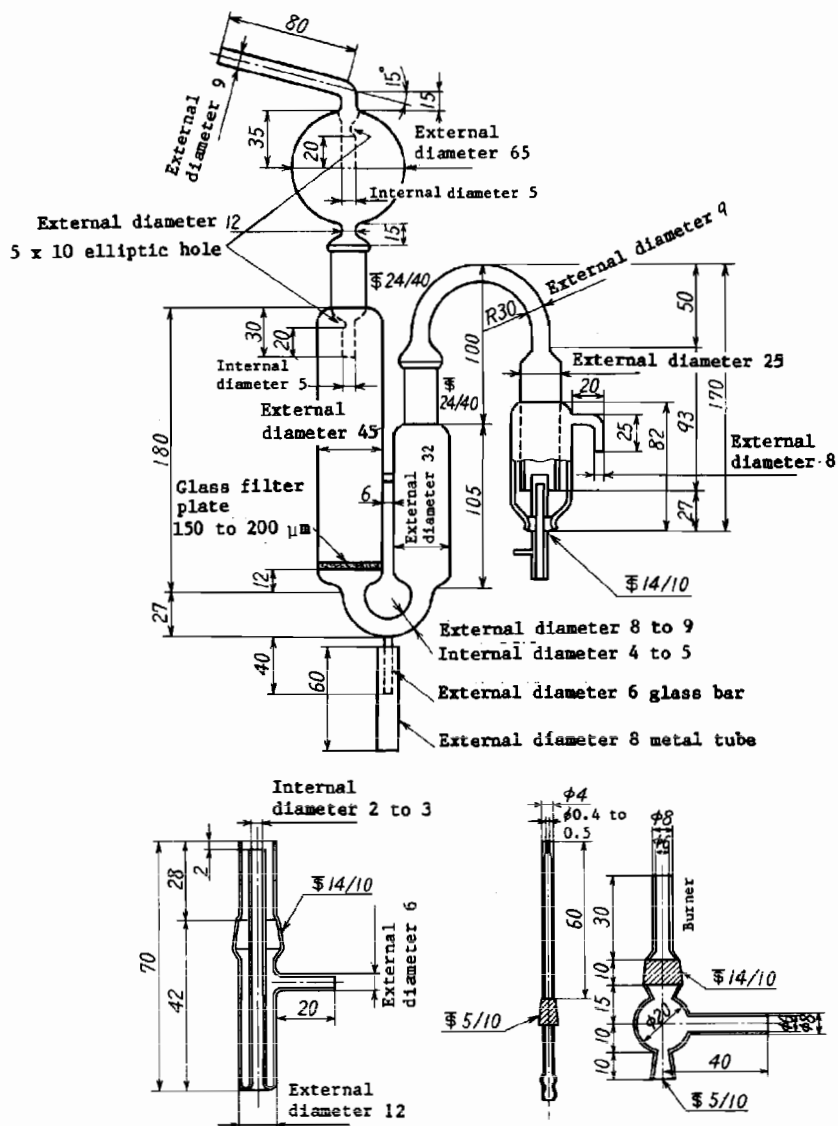


Fig. 19. Combustion tube, absorption tube, burner for method A combustion apparatus (An example)

Unit: mm



Type I burner (Hard grade 1 glass made)

Type II burner (Hard grade 1 glass made)

Remarks: As to burner, use either type I or type II.

(3.1.2) Combustion operation

- (a) Put absorption liquid 50 ml into absorbing tube.
- (b) Suck air at a flow rate of 140 to 180 l/h with a suction pump.
- (c) After detaching the burner from combustion tube, corresponding to the calorific value flow the sample gas at the flow rate indicated in Table 7, feed air to this from the wind feeding pump to ignite⁽¹²⁾, substitute sufficiently the gas sampling series until reaching burner with sample gas.
- (d) Insert the burner into combustion tube, simultaneously read the graduation of gas meter, and adjust the gas flow rate and air flow rate so as the flame burns gently and completely. In this case, keep such condition that soot does not generate at the upper part of combustion tube and bubbles in the absorption tube rise uniformly in the liquid in the degree not to spill in the spray trap.
- (e) After burning a suitable amount of sample gas, read the graduation of gas meter, immediately detach the burner, and stop the sample gas, suction pump and wind feeding pump.
- (f) From the reading of gas meter calculate the volume of sample gas used for combustion according to 4.5.

Note ⁽¹²⁾ Matches including sulphur content must not be used.

(3.2) Method B (Rapid method)

- (3.2.1) Apparatus An example of the method B combustion apparatus is shown in Fig. 20 and Fig. 21. Preliminarily pass sufficiently the sample gas through the gas meter and saturate the water in the meter with sample gas.

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Fig. 20. Method B combustion apparatus (An example)

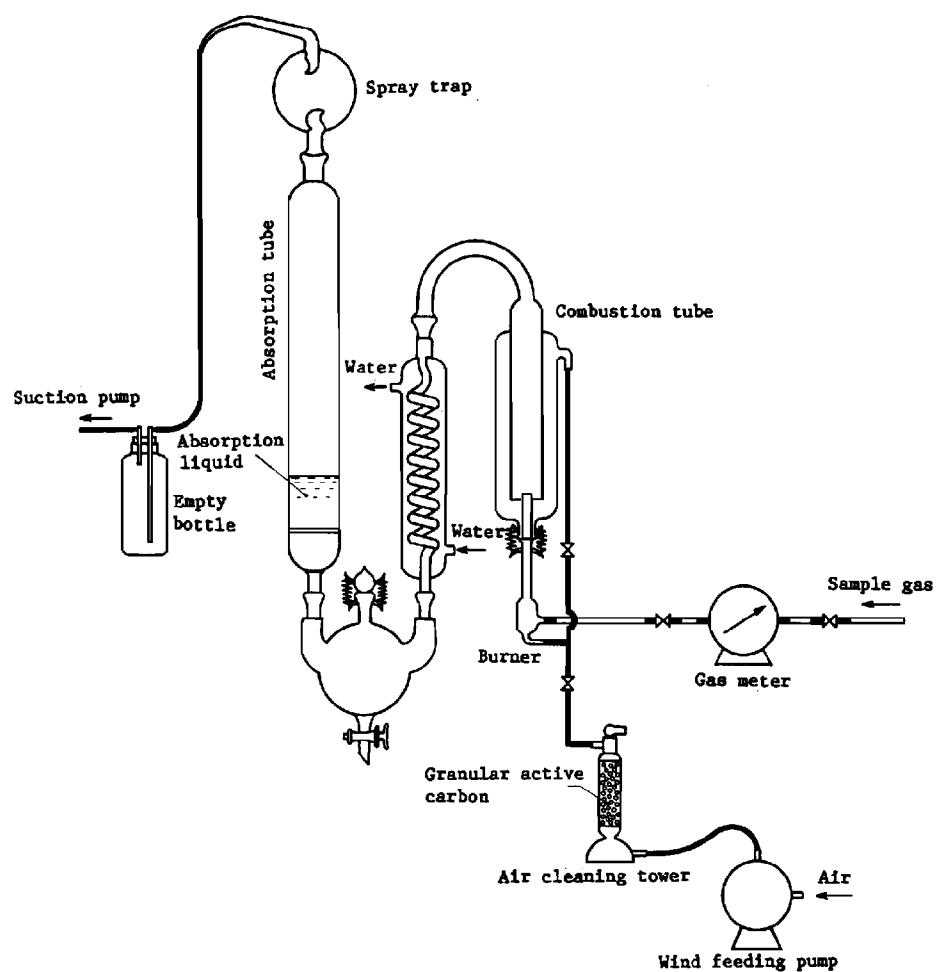
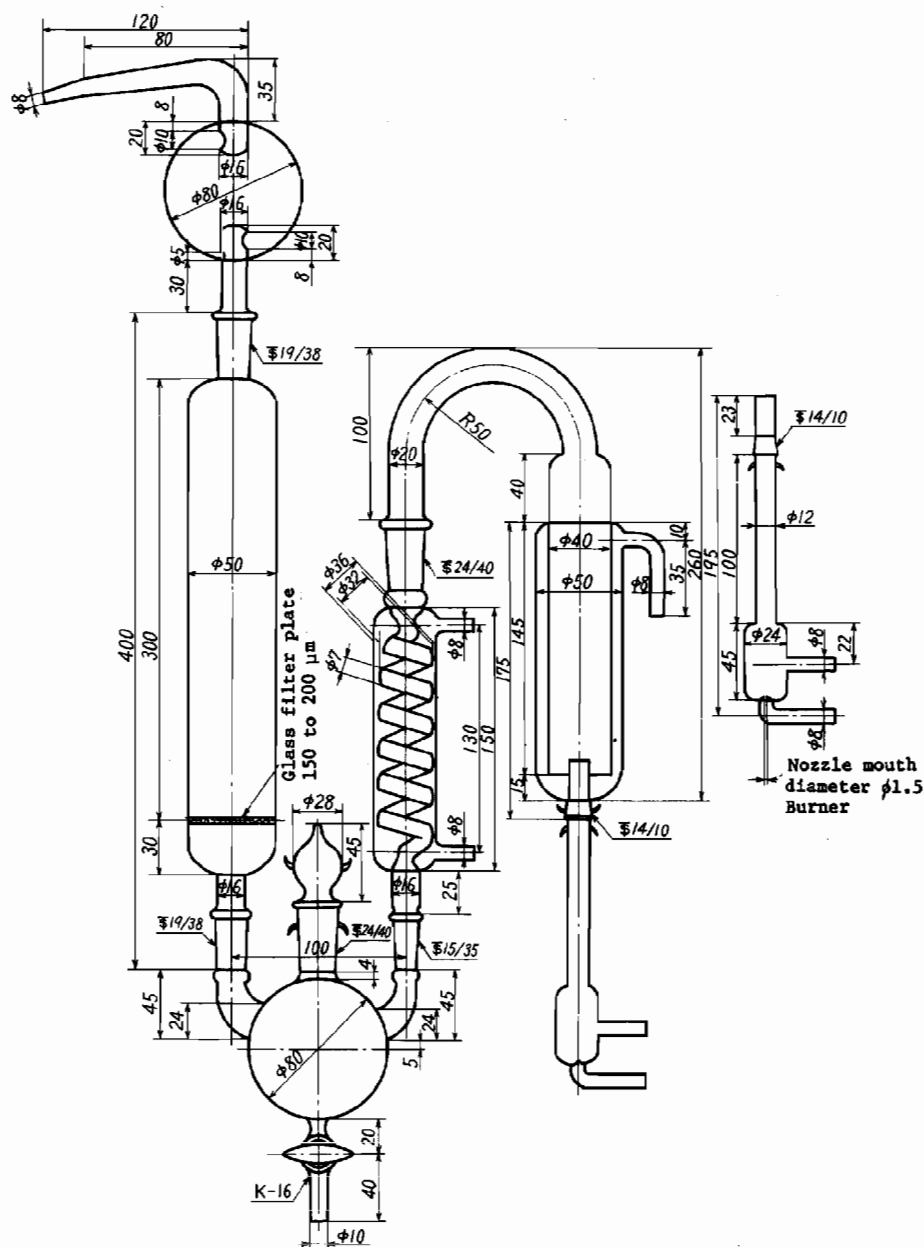


Fig. 21. Combustion tube, absorption tube, and burner for method B combustion apparatus (An example)



Remarks: As to the combustion tube and burner, use those made of hard grade 1 glass.

(3.2.2) Combustion operation

- (a) Detach the burner from combustion tube, flow the sample gas and air from the wind-feeding pump at a suitable flow rate to ignite⁽¹²⁾, and substitute the gas sampling series until reaching the burner with sample gas sufficiently.

- (b) After stopping the sample gas, insert the burner into combustion tube, and feed air from wind-feeding pump.
- (c) Detach the spray trap, and enter the absorption liquid 50 ml into absorbing tube.
- (d) Suck-in the air at a flow rate of 800 to 1000 l/h by suction pump, and after regulating the air amount, again connect the spray trap with the absorption tube.
- (e) Detach the burner from combustion tube, corresponding to the calorific value flow the sample gas at the flow rate indicated in Table 7, and while flowing the air at a rate of 500 to 800 l/h, ignite quickly⁽¹²⁾.
- (f) While viewing the condition of flame, make it normal Bunsen flame, insert the burner into combustion tube and simultaneously read the graduation of gas meter. Adjust the gas flow rate and air flow rate so as the flame to be in the complete-combustion condition.
- (g) After burning a suitable amount of sample gas, read the graduation of gas meter, immediately detach the burner, and stop the sample gas, suction pump and wind-feeding pump.
- (h) From the reading of gas meter, calculate the volume of sample gas used for combustion according to 4.5.

(3.3) Method C (Acid - hydrogen flame combustion method)

- (3.3.1) Apparatus An example of method C combustion apparatus is shown in Fig. 22 and Fig. 23. In this case, use that oil-less for suction pump, use vinyl tube or the like for connecting tube of cooling series, and bind the connecting part with a wire or the like.

Further, pass preliminarily the sample gas sufficiently through gas meter to saturate the water in the meter with sample gas and also perform preliminarily the purge of sample gas line sufficiently.

Fig. 22. Method C combustion apparatus (An example)

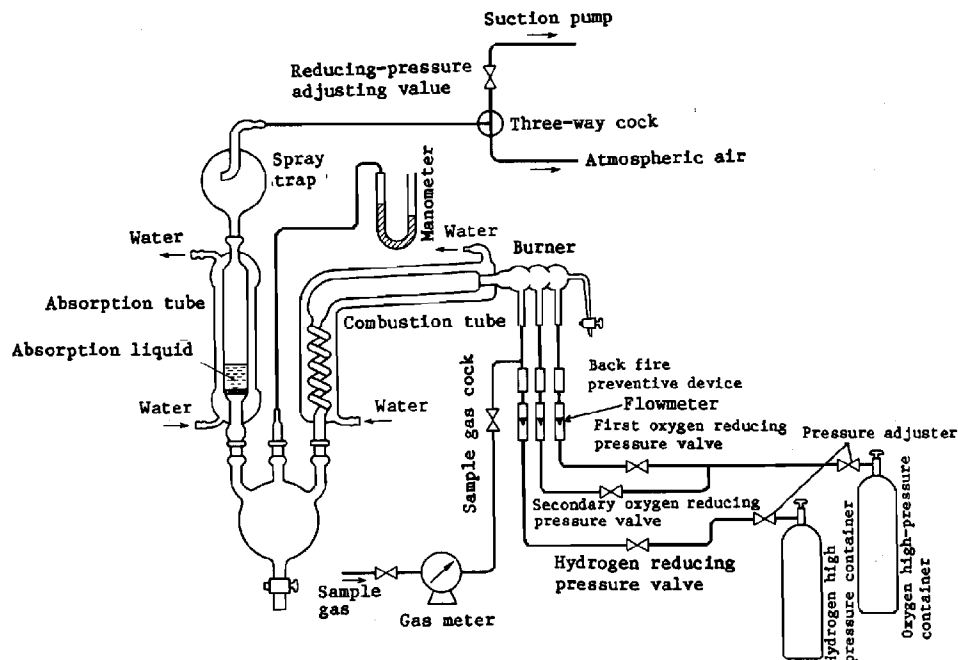
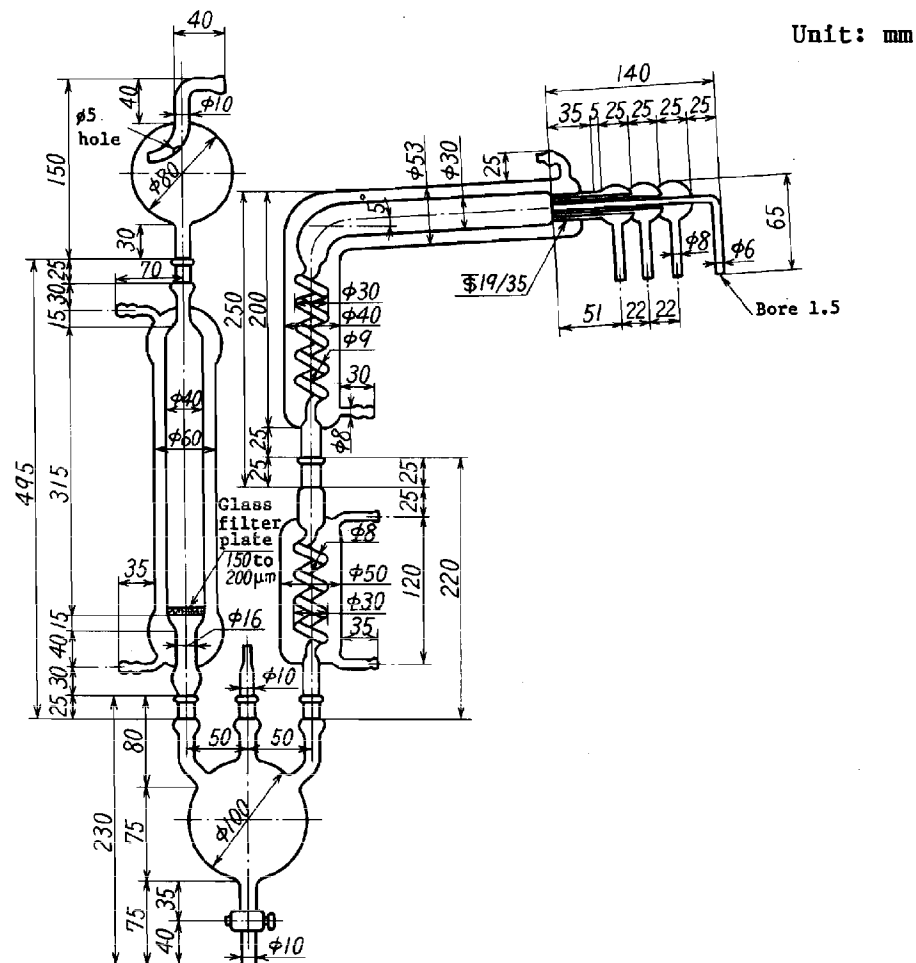


Fig. 23. Combustion tube, absorption tube, burner for method C combustion apparatus (An example)



Remarks: The burner and combustion tube made of quartz, and other parts made of hard grade 1 glass shall be used.

- (3.3.2) Combustion operation As to this method, because the high temperature combustion with acid-hydrogen flame is performed, it is required to take always into consideration for safety, to perform with attaching the protective devices such as face protector, protective eye glasses, leather gloves, etc. to the body. Particularly, it is required to establish preliminarily the countermeasures and procedures such as combustion interruption of sample, drawing out of burner, closing of hydrogen reducing pressure valve, etc. at the time of abnormalities such as suspension of water supply, interruption of electric service, stopping of vacuum pump, etc.

Further, because the operation method is different more or less according to the type of machine, perform the regulation for operation procedures, flow rates and pressures of oxygen and hydrogen, reducing-pressure degree in the system according to the instruction manual specified for each apparatus.

- (a) Confirm that the gas-piping connecting parts are free from leak and the insides of apparatus glass parts are clean.
- (b) Adjust the oxygen (specified in JIS K 1101) and hydrogen (grade 3 or grade 4 specified in JIS K 0512) from the high-pressure vessel to the specified pressure by the pressure adjuster.
- (c) Allow cooling water to flow to cooling series.
- (d) Confirm that the three-way code at the before flow of reducing pressure adjusting valve is at the atmosphere side, start the suction pump, insert the burner into combustion tube, while supporting lightly with hand open the first and secondary oxygen reducing pressure valves, and with viewing the flow meter adjust at the respective specified flow rates. Next, make the abovementioned three-way cock at the suction pump side, gradually open the reducing pressure valve and adjust the inside of series at the specified reducing-pressure degree.
- (e) Detach the spray trap, enter the absorption liquid 50 ml in absorption tube, and again return the spray trap to the original position.
- (f) Detach the burner from combustion tube, and support on holder. Open the sample gas cock and substitute the sample gas line with sample gas. After substituting, close the sample gas cock.
- (g) Open the hydrogen reducing-pressure valve, with viewing the flowmeter adjust at the specified flow rate, and substitute the air in the piping until reaching the burner.

- (h) With holding the burner on holder, ignite (¹²), and with taking care to confirm that the flame back-fire phenomenon is not caused(¹³). Next, with making so as the flame of burner not to contact with the ground connecting part of combustion tube as far as possible, quickly insert the burner into the combustion tube.
- (i) After confirming that the series inside is kept at the specified pressure, read the graduation of gas meter, gradually open the sample gas cock and burn the sample gas at the flow rate indicated in Table 7. At this time, adjust the length of flame suitably with sample gas cock or reducing-pressure adjusting valve and so make that incomplete combustion is not caused.

Further, in the case where the cooling water boils in the combustion tube, increase the amount of cooling water or make the combustion amount less.

- (j) After burning a suitable amount of sample gas, gradually close the sample gas cock and read the graduation of gas meter. Successively detach the burner from the combustion tube, and after fixing to holder, close the reducing-pressure valve in the sequence of hydrogen, first oxygen, secondary oxygen.
- (k) Stop the suction pump and cooling water, make the three-way cock at the atmospheric side and close the reducing pressure adjusting valve.
- (l) From the reading of gas meter, calculate the volume of sample gas used for combustion according to 4.5.

Note (¹³) The back-fire phenomenon can be recognized visually, but if the hand contacts the ground connecting part of burner, it is hot.
In case where the back-fire phenomenon is caused, the pressure of hydrogen should preferably be raised by a little amount.

(4) Determination operation The determination operation shall be in accordance with the following procedures:

- (4.1) Transfer the sample solution burned and absorbed the sample gas according to (3) with washing to a beaker (200 ml), and after adding Bromocresol Green solution 3 to 4 drops, add little by little the aqueous ammonia (1+200) until the color of solution turns to blue from yellow. Transfer this solution with washing to a measuring flask (250 ml), and add water up to the mark(¹⁴).
- (4.2) Separately take this solution 25 ml into a conical beaker (200 ml)(¹⁵) and add potassium chloride solution 1 ml, acetone 50 ml and dimethyl sulphonazo III solution 4 to 5 drops.

- (4.3) Titrate this solution while mixing by stirring with a magnetic stirrer by 1/200 mol barium perchlorate standard solution by using a microburette of 5 ml, and take the point when the color of solution has turned to green-blue color from purple and the color continued for 1 min as the end point.
- (4.4) As to the blank tests of method A and method B, relating to the absorption liquid through which only the air of the same flow rate and for the same time as in the case of sample and as to the method C, relating to the absorption liquid in which only hydrogen burned for the same time as in the case of sample, carry out the operation similar to (4.1) to (4.3).

Notes (¹⁴) At this time, in the case where the sample solution exceeds 250 ml, heat to concentrate by using an electrothermal hot plate or the like.

(¹⁵) In case where there is a fear of existing of metal ion in the sample solution, pass through cation exchange resin column to remove. In this case, it is required to decompose preliminarily hydrogen peroxide water by entering platinum net or the like in the sample solution and by boiling.

- (5) Calculation Calculate the total sulphur concentration in the sample gas according to the following formula.

$$C_s = \frac{0.160 \times f \times (a - b) \times 10}{V_0}$$

where, C_s : total sulphur concentration in sample gas (g/m³)

f : factor of 1/200 mol barium perchlorate standard solution

a : amount of 1/200 mol barium perchlorate standard solution required for titration of sample solution (ml)

b : amount of 1/200 mol barium perchlorate standard solution required for titration of blank test solution (ml)

V_0 : volume of sample gas under the standard condition calculated according to 4.5 (1)

However, in the case where a is not more than 10 times b , obtain C_s as $a = 10 \times b$, and express the result as "not more than determination limit (C_s g/m³)".

- (6) Expression of analysis result Express the analysis result by rounding off to significant numerals of two places according to JIS Z 8401.

6.2.2 Dimethylsulphonazo III absorptiometry

- (1) Summary Burn the sample gas by mixing with air or introducing into oxygen-hydrogen flame, allow to absorb the oxide of sulphur generated into the hydrogen perchlorate water and make sulphuric acid. Add N,N-dimethylformamid and barium perchlorate solution, after mixing, add dimethyl sulphonazo III solution, and measure the absorbance of generated chelate. This method, in the case where sample gas 20 l is taken, is possible to analyze the gas of 0.0025 to 0.02 g/m³ in total sulphur concentration.
- (2) Reagents Reagents shall be as follows:
 - (2.1) Absorbing liquid The absorbing liquid is the same as that of 6.2.1 (2.1).
 - (2.2) N,N-dimethylformamide The N,N-dimethylformamide specified in JIS K 8500.
 - (2.3) Standard potassium sulphate solution (0.003 mgS/ml) Dry the pulverized potassium sulphate specified in JIS K 8962 at 105 to 110°C for 2.5 to 3 h, weigh out its 0.163 g, transfer to a beaker (100 ml) and dissolve into a small amount of water. Transfer with washing this to a measuring flask (100 ml), add water up to the mark, and take it as the stock solution. Transfer this stock solution 10 ml by using a transfer pipette to a measuring flask (1 l) and add water up to the mark.
 - (2.4) Barium perchlorate solution (¹²) Weigh out the 1/200 mol barium perchlorate standard solution (factor f) 6/f ml prepared in 6.2.1 (2.7) into a measuring flask (100 ml) and add water up to the mark.
 - (2.5) Dimethylsulphonazo III solution Weigh out dimethyl sulphonazo III (2 sodium salt) 0.228 g, transfer to a beaker (200 ml), after dissolving into a small amount water, wash out to a measuring flask (500 ml) and add water up to the mark. Enter this solution into a brown color bottle, and preserve in a cool, dark place.
- (3) Combustion of sample gas The sample gas should preferably be burned according to the operation of 6.2.1 (3), as appropriate, until the total sulphur amount becomes 0.05 to 0.4 mg.
- (4) Determination operation The determination operation shall be performed according to the following sequence:
 - (4.1) Transfer the sample solution(¹⁵) which burned and absorbed the sample gas according to (3) with washing to a measuring flask (250 ml), and add water up to the mark. Successively, separately take this solution 10 ml into a measuring flask (25 ml).

- (4.2) Add N,N-dimethylformamide solution 10 ml and barium perchlorate solution 2 ml, mix by lightly shaking two to three times, after allowing to stand at room temperature for 30 min, add dimethylesulphonazo III solution 2 ml, lightly mix and add water up to the mark.
- (4.3) Transfer a part of this solution to an absorption cell, and measure the absorbance near 660 nm. As to the contrast solution, take the absorption liquid 10 ml into a measuring flask (25 ml), and operate similarly to (4.2). Provided that the barium perchlorate solution is not added.
- (5) Calculation Obtain the sulphur amount from the working curve prepared in (6), and calculate the total sulphur concentration in the sample gas according to the following formula.

$$C_s = \frac{A \times 25}{V_0}$$

where, C_s : total sulphur concentration in sample gas (g/m^3)

A : sulphur amount in coloring solution obtained from the working curve (mg)

V_0 : volume of sample gas under the standard condition calculated according to 4.5 (l)

However, in the case where A is less than 0.002 mg, by making $A = 0.002$ mg obtain C_s and express the result as "not more than determination limit ($C_s \text{ g/m}^3$)".

- (6) Preparation of working curve Take step by step each type solution amount of standard potassium sulphate solution 0 to 5 ml (0 to 0.015 mg as sulphur) into several measuring flasks (25 ml), dilute the amount of solution to 10 ml by adding water, hereafter operate according to the procedures on and after (4.2) and prepare the relation curve between the obtained absorbance and the amount of sulphur and take it as the working curve.
- (7) Expression of analysis results Express the analysis results by rounding off to two significant numerals according to JIS Z 8401.

6.3 Method for chemical analysis of hydrogen sulphide

6.3.1 Iodine titrimetric method

- (1) Summary After making hydrogen sulphide zinc sulphide by passing a sample gas through absorption solution, the precipitate is filtered, decomposed with iodine solution and hydrochloric acid and back-titrated with sodium thiosulphate solution. When 150 l of the sample gas is sampled, the gas of $0.01 \text{ g/m}^3 \text{ min.}$ in hydrogen sulphide concentration can be analyzed by this method.

- (2) Apparatus An example of absorption apparatus is given in Fig. 24. As for the absorption bottle, three gas cleaning bottles given in Fig. 25 are used and connected with soft vinyl tubes.

Fig. 24. Hydrogen sulphide absorption apparatus
(An example)

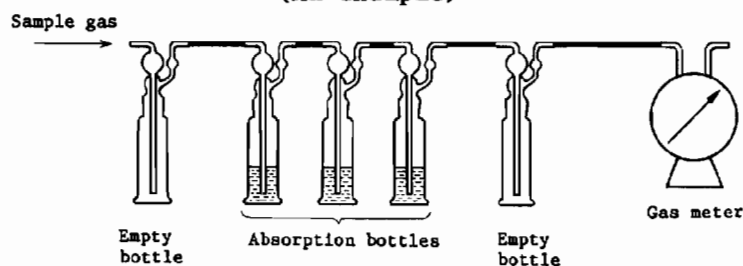
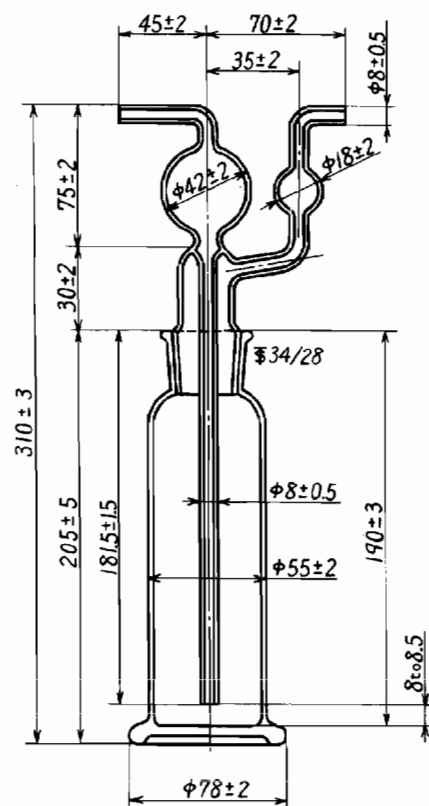


Fig. 25. Gas cleaning bottle (250 ml) (An example)

Unit: mm



- (3) Reagents The reagents shall be as follows:

- (3.1) Absorption solution 5 g zinc sulphate (7 hydrate) specified in JIS K 8953 is dissolved with about 500 ml water, joined by the solution obtained by dissolving 6 g sodium hydroxide specified in JIS K 8576 with about 300 ml water and further, joined by 70 g ammonium sulphate specified in JIS K 8960 mixing them by stirring. When the precipitate of zinc hydroxide has been dissolved, it is diluted to 1 l in total amount by adding water.

(3.2) Hydrochloric acid (1+1)

(3.3) Iodine solution (1/20 mol) After dissolving 40 g potassium iodide specified in JIS K 8913 with about 25 ml water, it is joined by about 13 g iodine specified in JIS K 8920 and further, joined by about 1 l water and 3 drops of hydrochloric acid specified in JIS K 8180.

(3.4) Standard 1/20 mol potassium iodate solution Potassium iodate (standard reagent) specified in JIS K 8922 is dried at 120 to 140°C for 2 h and let to stand to cool in a desiccator with sulfuric acid. Thereafter, 3.567 g thereof is weighed out, transferred into a beaker (200 ml) and dissolved with a small amount of water. It is transferred into a measuring flask (1 l) by washing and dilute up to the mark by adding water.

(3.5) 1/20 mol sodium thiosulphate standard solution After dissolving 26 g sodium thiosulphate specified in JIS K 1420 and 0.20 g sodium carbonate (anhydrous) specified in JIS K 8625 with 1 l water containing no carbonic acid, it is joined by 10 ml isoamyl alcohol specified in JIS K 8051, sufficiently mixed by shaking and let to stand for 2 days. The standardization thereof is carried out as follows:

25 ml standard 1/20 mol potassium iodate solution is taken into a flask with ground stopper (500 ml) by means of a transfer pipette and joined by about 300 ml water, 2 g potassium iodide and 5 ml sulphuric acid (1+5). Thereafter, it is immediately stoppered, quietly mixed by shaking and let to stand in a dark place for 5 min.

Hereafter, the operation is carried out in the same way as in (4.4). Separately, a blank test is carried out by using water and the factor is calculated from the following formula:

$$f = \frac{25}{a-b}$$

where, f : factor of 1/20 mol sodium thiosulphate standard solution

a : amount of 1/20 mol sodium thiosulphate standard solution required for initial titration (ml)

b : amount of 1/20 mol sodium thiosulphate standard solution required for blank test (ml)

(3.6) Starch solution 1 g starch (soluble) specified in JIS K 8659 is mixed with about 30 ml water, added into 200 ml hot water while mixing them by stirring and boiled for about 1 min. Thereafter, it is cooled. This solution is prepared at each service.

(4) Operation The determination operation shall be carried out in accordance with the following procedures:

- (4.1) After putting 100 ml absorption solution into three absorption bottles respectively, pass the sample gas at a flow rate of 15 to 30 l/h until 1.5 to 50 mg as amount of hydrogen sulphide is absorbed to be the sample solution. Read the gas meter and calculate the volume of sample gas taken in accordance with 4.5.
- (4.2) Filter the sample solution with the glass filter (separation type) equipped with a membrane filter (0.5 μm max. in hole diameter) and sufficiently wash the inside of absorption bottle, the wall of glass filter and the precipitate with water.
- (4.3) Transfer the precipitate together with the glass filter into a beaker (300 ml) and dissolve the precipitate by adding 40 ml iodine solution (1/20 mol) and 10 ml hydrochloric acid (1+1). Wash the glass filter and the membrane filter with water and take them out from the beaker.
- (4.4) Titrate this solution with 1/20 mol sodium thiosulphate standard solution while mixing this solution by stirring with a magnetic stirrer. When the color of solution turns to light yellow, add 1 ml starch solution as indicator, continue to titrate it and allow the point at which blue purple disappears to be the end point.
- (4.5) Carry out the operations of (4.2) to (4.4) by using 300 ml absorption solution as the blank test.

- (5) Calculation The concentration of hydrogen sulphide in the sample gas shall be calculated from the following formula:

$$C_{\text{H}_2\text{S}} = \frac{1.704 \times f \times (b - a)}{V_0}$$

where, $C_{\text{H}_2\text{S}}$: concentration of hydrogen sulphide in sample gas (g/m^3)

f : factor of 1/20 mol sodium thiosulphate standard solution

a : amount of 1/20 mol sodium thiosulphate standard solution required for titration of sample solution (ml)

b : amount of 1/20 mol sodium thiosulphate standard solution required for titration of blank test solution (ml)

V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (l)

- (6) Expression of analysis result Express the analysis result by rounding off to significant two numerals according to JIS Z 8401.

6.3.2 Methylene blue absorptiometry

- (1) **Summary** The sample gas is passed through absorption solution and hydrogen sulphide is absorbed. The solution is joined by dimethyl-*p*-phenylene-diamine hydrochloride and ferric chloride, and the absorbance of generated Methylene Blue is measured. When 5 l of the sample gas is taken, the gas of 0.001 to 0.03 g/m³ in hydrogen sulphide concentration can be analyzed by this method.
- (2) **Apparatus** An example of absorption apparatus is shown in Fig. 26. As for the absorption bottle, two gas cleaning bottles given in Fig. 25 or otherwise one whole coloring bottle given in Fig. 27 are used and connected with flexible vinyl tubes.

Fig. 26. Hydrogen sulphide absorption apparatus
(An example)

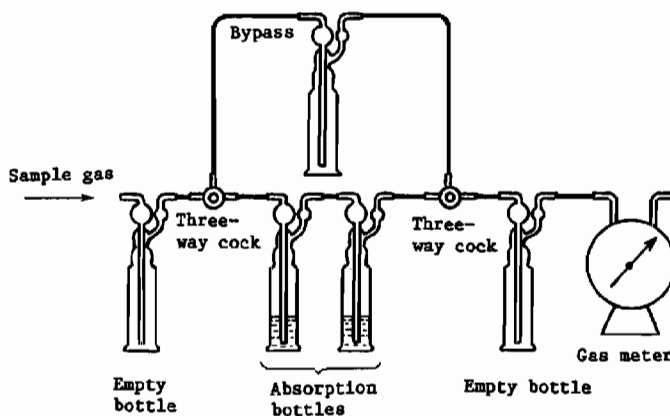
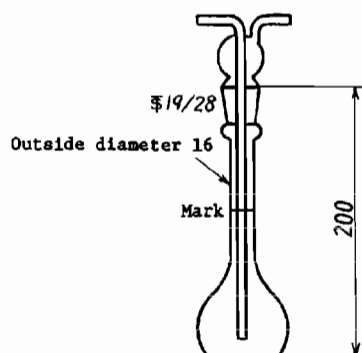


Fig. 27. Whole coloring bottle (50 ml) (An example)

Unit: mm



Remarks: Respective dimensions in the figure indicate standard dimensions.

(3) Reagents The reagents shall be as follows:

- (3.1) Absorption solution Ditto in 6.3.1 (3.1).
- (3.2) Ferric chloride solution 1.0 g ferric chloride (6 hydrate) specified in JIS K 8137 is dissolved with 100 ml sulphuric acid (1+100).
- (3.3) Iodine solution (1/20 mol) Ditto in 6.3.1 (3.3).
- (3.4) Dimethyl-*p*-phenylenediamine hydrochloride solution 0.10 g dimethyl-*p*-phenylenediamine hydrochloride specified in JIS K 8193 is dissolved with 100 ml sulphuric acid (1+3).
- (3.5) Hydrogen sulphide standard solution (0.001 mg H₂S/ml) About 1 g colorless crystalline sodium sulphide (9 hydrate) specified in JIS K 8949 is dissolved with water containing no oxygen to 100 ml and 10 ml thereof is taken. It is joined by 25 ml iodine solution (1/20 mol) and 1 ml hydrochloric acid specified in JIS K 8180, stoppered and let to stand for 10 min. Thereafter, it is joined by starch indicator and titrated with 1/20 mol sodium thiosulphate standard solution (*f* in factor) (*a* ml in titre). Separately as the blank test, the same operation is carried out without using sodium sulphide solution (*b* ml in titre).

$[117.6/(b-a)f]$ ml is immediately taken into a measuring flask (100 ml) and diluted up to the mark by adding water to be the stock solution. 5 ml of this stock solution is taken into a measuring flask (1 l) and diluted up to the mark by adding absorption solution.

Hydrogen sulphide standard solution and the stock solution are prepared at each service.

- (3.6) 1/20 mol sodium thiosulphate standard solution Ditto in 6.3.1 (3.5).
- (4) Operation The operation shall be carried out in accordance with the following procedures. The following operation shall be always carried out avoiding the direct rays of the sun.
- (4.1) Respectively put 50 ml absorption solution into two absorption bottles. When a whole coloring bottle is used, put 30 ml absorption solution thereinto.
- (4.2) After sufficiently displacing the inside of the piping to the absorption bottle via bypass passage with the sample gas, switch the three-way cock and pass the sample gas at a flow rate of 15 to 30 l/h until 0.025 to 0.15 mg as hydrogen sulphide amount (0.005 to 0.03 mg when the whole coloring bottle is used) is absorbed to be the sample solution. Read the gas meter and calculate the volume of sample gas taken in accordance with 4.5.

- (4.3) Transfer the sample solution into a one mark volumetric flask (200 ml), wash the absorption bottle and the piping part with absorption solution, join them together and further add absorption solution up to the mark. Successively, separately take 40 ml of this solution into a measuring flask (50 ml). When a whole coloring bottle is used, carry out the operation on and after (4.4) concerning total amount of sample solution of (4.2).
- (4.4) Add 4 ml dimethyl-*p*-phenylenediamine hydrochloride solution, successively add 2 ml ferric chloride solution, stopper the flask and mix them by quietly turning over the flask 2 times. Thereafter, add absorption solution up to the mark and allow the solution to stand at room temperature for 30 min.
- (4.5) Transfer a portion of this solution into an absorption cell and measure the absorbance at near 670 nm. As for the contrast solution, take 40 ml absorption solution into a measuring flask (50 ml) and operate it in the same way as in (4.4) to be the contrast solution.
- (5) Calculation The amount of hydrogen sulphide shall be obtained from the working curve prepared in (6) and the concentration of hydrogen sulphide in sample gas shall be calculated from the following formula:
- $$C_{H_2S} = \frac{A}{V_0 \times B}$$
- where, C_{H_2S} : concentration of hydrogen sulphide in sample gas (g/m³)
- A : amount of hydrogen sulphide in coloring solution obtained from the working curve (mg)
- V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (l)
- B : aliquot ratio of sample solution, 1/5 (however, 1 in the case of using a whole coloring bottle)
- (6) Preparation of working curve Step by step take various amounts of 0 to 30 ml hydrogen sulphide standard solution (0 to 0.03 mg as hydrogen sulphide) just after preparation into several measuring flasks (50 ml), dilute each amount of solution to 40 ml by adding absorption solution, hereafter carry out the operation in accordance with the procedures on and after (4.4) and prepare the relation curve between the obtained absorbance and the amount of hydrogen sulphide to be the working curve.
- (7) Expressing of analysis result Round off the analysis result to significant two numerals according to JIS Z 8401 to express.

6.3.3 Lead acetate test paper method

- (1) Summary Sample gas is contacted to the filter paper immersed in lead acetate solution and the presence of the discoloration of filter paper is inspected. When several mg/m^3 hydrogen sulphide is contained in the sample gas, the filter paper is discolored by this method.
- (2) Devices The test devices are given in Fig. 28 and Fig. 29.

Fig. 28. Tester (An example)

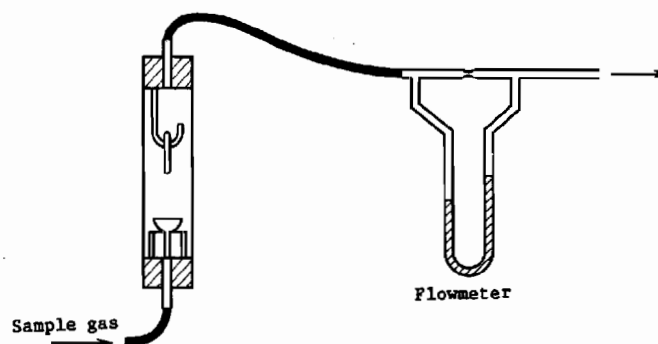
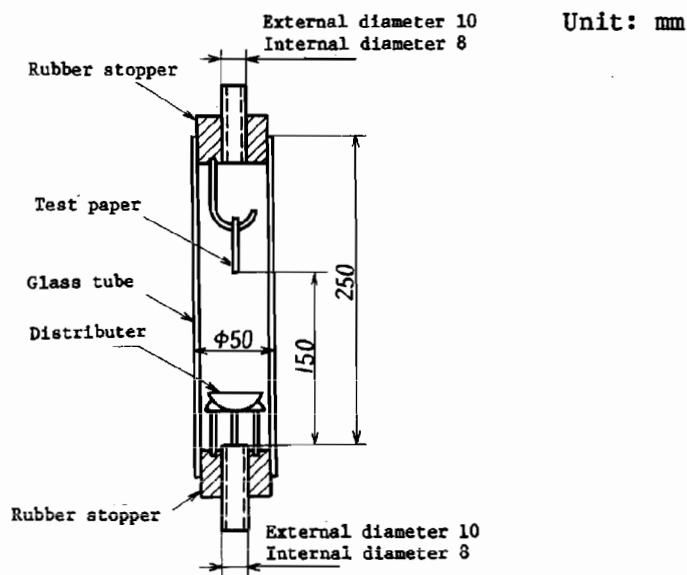


Fig. 29. Detail figure of tester (An example)



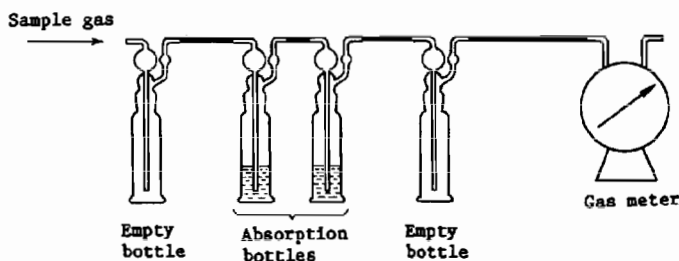
- (3) Reagent and test paper The reagent and the test paper shall be as follows:
- (3.1) Lead acetate solution 5.0 g lead acetate (tri-hydrate) specified in JIS K 8374 is dissolved with 100 ml water and tightly stoppered to be stored. When turbidity is generated by absorption of carbon dioxide in air, the solution is filtered to be used.
- (3.2) Test paper A qualitative filter paper specified in JIS P 3801 cut by about 3 cm in length and 1 cm in width.
- (4) Operation The operation shall be carried out in accordance with the following procedures:
- (4.1) Regulate the flow rate of sample gas at 2.5 l/min.
- (4.2) Immerse 2 pieces of test paper into lead acetate solution and immediately draw them up.
- (4.3) Hang one piece of these wetted test papers inside the tester and contact it to sample gas for one min.
- (4.4) Take it out, compare it with another piece and inspect for the presence of the discoloration to faint yellow or black brown.
- (5) Expression of analysis result Express whether the test paper shows discoloration or not.

6.4 Method for chemical analysis of ammonia

6.4.1 Neutralization titrimetric method

- (1) Summary Ammonia is absorbed by passing sample gas through boric acid solution and this solution is titrated with sulphuric acid. When the influences of other basic gas and acidic gas can be neglected, this method is applied. When 50 l of the sample gas is taken, the gas of 0.07 g/m³ min. in ammonia concentration can be analyzed by this method.
- (2) Apparatus An example of absorption apparatus is given in Fig. 30. For the absorption bottle, two gas cleaning bottles given in Fig. 25 are used and connected with flexible vinyl tube.

Fig. 30. Ammonia absorption apparatus (An example)



(3) Reagents The reagents shall be as follows:

- (3.1) Absorption solution Boric acid solution (5 g/l)
- (3.2) Standard 1/20 mol sodium carbonate solution 1 to 1.5 g sodium carbonate (standard reagent) specified in JIS K 8625 is put into a platinum crucible and heated at 500 to 650°C for 40 to 60 min. After standing to cool in a desiccator with sulphuric acid, its mass is weighed out to the nearest 0.1 mg, transferred into a beaker (100 ml) and dissolved with a small amount of water. It is transferred into a measuring flask (250 ml) by washing and diluted up to the mark by adding water.
- (3.3) 1/20 mol sulphuric acid standard solution The beaker preliminarily containing 100 ml water is gradually added by 3 ml sulphuric acid specified in JIS K 8951. The solution is sufficiently mixed and diluted to 1 l by adding water. The standardization thereof shall be carried out as follows:

25 ml standard 1/20 mol sodium carbonate solution is taken into a conical beaker (200 ml) with a transfer pipette. After adding several drops of Bromophenol Blue indicator [0.10 g Bromophenol Blue specified in JIS K 8844 is dissolved with 20 ml ethyl alcohol (95) specified in JIS K 8102 and diluted to 100 ml by adding water. This solution is stored in a brown bottle], the solution is titrated with prepared 1/20 mol sulphuric acid standard solution and carbon dioxide is expelled by boiling the solution at near the end point. After cooling, it is titrated until the color of solution turns to yellow (3 in pH) and the factor is calculated from the following formula:

$$f = \frac{25 \times \frac{w}{1.325}}{a}$$

where, f : factor of 1/20 mol sulphuric acid standard solution

w : mass of sodium carbonate weighed out in (3.2) (g)

a : amount of 1/20 mol sulphuric acid standard solution required for titration (ml)

- (3.4) Methyl red-methylene blue mixed indicator 0.20 g methyl red specified in JIS K 8896 dissolved with 100 ml ethyl alcohol (95) specified in JIS K 8102 and 0.10 g Methylene Blue specified in JIS K 8897 dissolved with 100 ml ethyl alcohol (95) are mixed by the same volume, put in a brown bottle and stored in a cool, dark place. After storing for several days, it shall not be used. The discoloring point of this indicator exists at 5.4 in pH.
- (4) Operation The operation shall be carried out in accordance with the following procedures:

- (4.1) After respectively putting 50 ml absorption solution into two absorption bottles, pass the sample gas through at a flow rate of 60 to 120 l/h until 3.5 mg min. as ammonia amount is absorbed to prepare the sample solution. Read the gas meter and calculate the volume of sample gas taken in accordance with 4.5.
- (4.2) Transfer the sample solution into a measuring flask (250 ml), wash the absorption bottle and the piping part with absorption solution, join together washings to the sample solution and further dilute it up to the mark by adding absorption solution.
- (4.3) Separately take 50 to 100 ml of this solution into a conical beaker (200 ml), add several drops of Methyl Red-Methylene Blue mixed indicator, titrate it with 1/20 mol sulphuric acid standard solution while mixing them by stirring with a magnetic stirrer and allow the point at which it turns to reddish purple to be the end point.
- (4.4) As for a blank test, carry out the operation of (4.3) by using absorption solution.
- (5) Calculation The concentration of ammonia in sample gas shall be calculated from the following formula:

$$C_{\text{NH}_3} = \frac{1.703 \times f \times (a - b)}{V_0 \times B}$$

where, C_{NH_3} : concentration of ammonia in sample gas (g/m^3)

f : factor of 1/20 mol sulphuric acid standard solution

a : amount of 1/20 mol sulphuric acid standard solution required for titration of sample solution (ml)

b : amount of 1/20 mol sulphuric acid standard solution required for titration of blank test solution (ml)

B : aliquot ratio of sample solution for titration

V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (l)

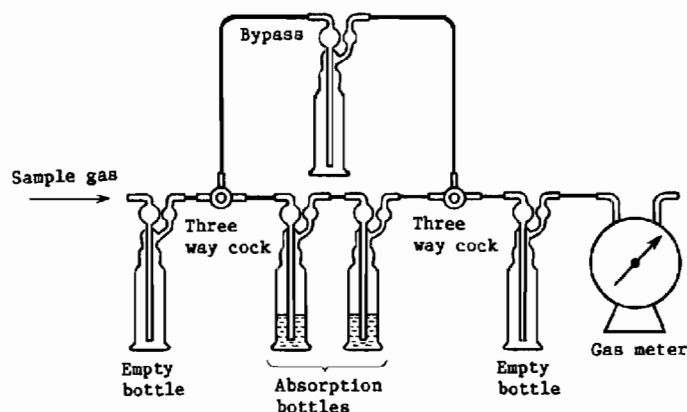
- (6) Expression of analysis result Round off the analysis result to two significant numerals according to JIS Z 8401 to express.

6.4.2 Indophenol absorptiometry

- (1) Summary Ammonia is absorbed by passing sample gas through boric acid solution and the absorbance of indophenol blue generated by adding phenol-sodium nitroprusside and sodium hypochlorite is measured. When the influence of hydrogen sulphide can be neglected, this method is applied and when 5 l of the sample gas is taken, the gas of 0.001 to 0.07 g/m^3 in ammonia concentration can be analyzed by this method.

- (2) Apparatus An example of absorption apparatus is given in Fig. 31. For the absorption bottle, two gas cleaning bottles given in Fig. 25 are used and connected with a flexible vinyl tube.

Fig. 31. Ammonia absorption apparatus (An example)



- (3) Reagents The reagents shall be as follows:

(3.1) Absorption solution Ditto in 6.4.1 (3.1).

(3.2) Sodium hypochlorite solution (1 g/l in effective chlorine concentration) $1000/C_{cl}$ sodium hypochlorite solution (C_{cl} in effective chlorine concentration) and 15 g sodium hydroxide are dissolved with water to 1 l.

When stored in a cold dark place, this solution is stable for one month.

The effective chlorine concentration C_{cl} of this solution shall be obtained according to the following operation:

v ml sodium hypochlorite solution is taken into a measuring flask (200 ml) and diluted up to the mark by adding water. 10 ml of this solution is separately taken into an Erlenmeyer flask (300 ml) with ground stopper and diluted to about 100 ml by adding water. Then, it is joined by 1 to 2 g potassium iodide and 6 ml acetic acid (1+1), tightly stoppered, sufficiently mixed by shaking and allowed to stand in a dark place for 5 min. Thereafter, it is titrated with 1/40 mol sodium thiosulphate standard solution. When the color of solution turns to faint yellow, the solution is joined by 3 ml starch solution as indicator, successively titrated and the point at which its blue purple color disappears is taken as the end point.

A blank test is separately carried out by using water and the concentration of effective chlorine shall be calculated from the following formula.

$$C_{\text{cl}} = \frac{0.1773 \times f \times (a - b) \times 200}{v}$$

where, C_{cl} : effective chlorine concentration (g/l)
 f : factor of 1/40 mol sodium thiosulphate standard solution
 a : amount of 1/40 mol sodium thiosulphate standard solution required for initial titration (ml)
 b : amount of 1/40 mol sodium thiosulphate standard solution required for blank test (ml)
 v : sampled amount of sodium hypochlorite solution (ml)

(3.3) Phenol-sodium nitroprusside solution 5.0 g phenol specified in JIS K 8798 and 25 mg sodium nitroprusside specified in JIS K 8722 are dissolved with water to 500 ml. When this solution is put in a brown bottle and stored in a cold dark place, it is stable for one month.

(3.4) Standard ammonia solution (0.002 mgNH₃/ml) Ammonium sulphate specified in JIS K 8960 is dried at 130°C. 3.879 g thereof is weighed out, transferred into a beaker (200 ml) and dissolved with a small amount of water. It is transferred into a measuring flask (1 l) by washing and diluted up to the mark by adding water to be the stock solution. This stock solution is further diluted 500 times with absorption solution to be the ammonia standard solution.

(4) Operation The operation shall be carried out in accordance with the following procedures:

(4.1) Respectively put 50 ml absorption solution into two absorption bottles. After sufficiently replacing the inside of the piping up to the absorption bottles via the bypass passage with sample gas, change over the three-way cock and pass the sample gas at a flow rate of 60 to 120 l/h until 0.005 to 0.35 mg as ammonia amount is absorbed to prepare the sample solution. Read the gas meter and calculate the volume of sample gas taken in accordance with 4.5.

(4.2) Transfer the sample solution into a measuring flask (250 ml), wash the absorption bottles and the piping part with absorption solution, join together washings thereto and further add absorption solution up to the mark. Successively, separately take 10 ml of this solution into a dry measuring flask (20 ml).

(4.3) Add 5 ml phenol-sodium nitroprusside and sufficiently mix them by shaking. Thereafter, add sodium hypochlorite solution up to the mark and quietly mix them by shaking. Allow it to stand at 25 to 30°C for 1 h.

- (4.4) Transfer a portion of this solution into an absorption cell and measure the absorbance at nearly 640 nm. As for the contrast solution, take 10 ml absorption solution into a dry one mark volumetric flask (20 ml) and operated it in the same way as in (4.3) to be the contrast solution.
- (5) Calculation The amount of ammonia shall be obtained from the working curve prepared in (6) and the concentration of ammonia in sample gas shall be calculated from the following formula:
- $$C_{\text{NH}_3} = \frac{A \times 25}{V_0}$$
- where C_{NH_3} : concentration of ammonia in sample gas (g/m^3)
 A : amount of ammonia in coloring solution obtained from working curve (mg)
 V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (l)
- (6) Preparation of working curve Stepwise take various amounts of 0 to 10 ml standard ammonia solution (0 to 0.02 mg as ammonia) into several dry measuring flasks (20 ml), dilute the amount of solution to 10 ml by adding absorption solution to each of them, hereafter carry out the operation in accordance with the procedures on and after (4.3) and prepare the relation curve between the obtained absorbance and the amount of ammonia to be the working curve.

Remarks: When the working curve is confirmed to be the straight line passing the origin, prepare two dry measuring flasks (20 ml), take 5 ml standard ammonia solution and 5 ml absorption solution into one flask and 10 ml sample solution into another flask, hereafter carry out the operation on and after (4.3), measure the absorbance and allow the concentration of ammonia in sample gas to be calculated from the following formula:

$$C_{\text{NH}_3} = \frac{\frac{A}{A_1} \times 0.25}{V_0}$$

where, C_{NH_3} : concentration of ammonia in sample gas (g/m^3)
 A : absorbance of sample solution
 A_1 : absorbance of ammonia standard solution
 V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (l)

- (7) Expression of analysis result Round off the analysis result to two significant numerals according to JIS Z 8401 to express the result.

6.4.3 Silver nitrate - manganese nitrate test paper method

- (1) Summary Sample gas is contacted to the filter paper immersed in the mixed solution of silver nitrate, manganese nitrate and nitric acid and the presence of the discoloration of filter paper is inspected. When about 0.1 g/m^3 ammonia is contained in the sample gas, the filter paper is discolored by this method.
- (2) Apparatus Ditto in 6.2.3 (2).
- (3) Reagent and test paper The reagent and the test paper shall be as follows:
 - (3.1) Silver nitrate - Manganese nitrate mixed solution 3.5 g silver nitrate specified in JIS K 8550 is dissolved with 40 ml water, mixed with the solution obtained by dissolving 3.0 g manganese nitrate (6 hydrate) specified in JIS K 8568 with 40 ml water and further joined by 2 ml nitric acid of about 1 mol (obtained by adding water to 7.5 ml nitric acid to 100 ml). Thereafter, it is diluted to 100 ml by adding water. When stored in a brown bottle, this solution is stable for one month.
 - (3.2) Test paper A filter paper specified in JIS P 3801 (class 5 A for determination analysis use) cut by 3 cm in length and 1 cm in width.
- (4) Operation The operation shall be carried out in accordance with the following procedures:
 - (4.1) Regulate the flow rate of sample gas at 2.5 l/min .
 - (4.2) Immerse two pieces of test paper into silver nitrate - manganese nitrate mixed solution to about $1/3$ (about 1 cm) of the longitudinal direction and immediately draw them up. At that time, make the boundary of the solution absorbed with the test paper be about $1/2$ (about 1.5 cm) of the longitudinal direction.
 - (4.3) Hang one piece of this test paper in the test apparatus and contact it with the sample gas for 1 min.
 - (4.4) Take it out, compare it with another piece and inspect whether the boundary between the wet part of filter paper and the not wet part is discolored to black in a belt state.
- (5) Expression of analysis result Express whether the discoloration of test piece is confirmed or not.

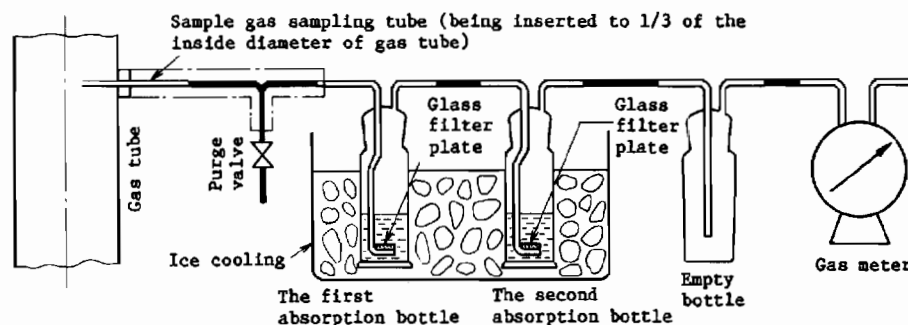
6.5 Method for chemical analysis of naphthalene (gas chromatography)

(1) Summary Naphthalene is absorbed by passing sample gas through toluene cooled with ice and it is determined by inner standard method by using a gas chromatograph. When 300 l the sample gas is taken and a heat conductivity type detector is used, the gas of 0.01 g/m^3 min. in naphthalene concentration can be analyzed by this method. In that case, when a hydrogen flame ionization type detector is used, the gas of 0.01 g/m^3 max. can be analyzed, too.

(2) Apparatus The apparatus shall be as follows:

(2.1) Absorption apparatus An example of absorption apparatus is given in Fig. 32. As for the absorption bottle, two absorption bottles (with glass filter plate or ball) given in Fig. 163 of JIS K 2839 are used. The piping from the sample gas sampling tube to the absorption bottles are thermally insulated so that naphthalene in sample gas is not deposited.

Fig. 32. Naphthalene absorption apparatus (An example)



(2.2) Gas chromatograph

- (a) Detector It is a heat conductivity type detector or hydrogen flame ionization type detector. As for the required sensitivity of detector, when $5 \times 10^{-7} \text{ g}$ naphthalene for the heat conductivity type detector and $5 \times 10^{-8} \text{ g}$ naphthalene for the hydrogen flame ionization type detector are respectively inducted, the peak height of chromatogram shall necessarily be 10 mm min.
- (b) Carrier gas It is helium of 99.9 % min. in purity. When a hydrogen flame ionization type detector is used, nitrogen of 99.9 % min. may be used.
- (c) column The glass tube or stainless steel tube of 3 to 5 mm in inside diameter and 2 m in length is filled with the packaging substance obtained by impregnating acid treated brown diatomaceous earth carrier [250 to 590 μm (60 to 30 mesh)] with FFAP (Free fatty acid polyester) by 10 %.

- (2.3) Recorder Ditto in 5.3.3.
- (2.4) Date processor Ditto in 5.3.4.
- (3) Reagents The reagents shall be as follows:
- (3.1) Absorption solution The absorption solution is toluene specified in JIS K 8680.
- (3.2) Standard naphthalene solution 0.300 g naphthalene specified in JIS K 8690 is weighed out, transferred into a beaker (100 ml) and dissolved with a small amount of toluene. It is transferred into a measuring flask (100 ml) by washing and diluted up to the mark by adding toluene.
- (3.3) Inner standard material solution 0.300 g *n*-heptadecane is weighed out, transferred into a beaker (100 ml) and dissolved with a small amount of toluene. It is transferred into a one mark volumetric flask (100 ml) by washing and diluted up to the mark by adding toluene.
- (4) Operation The operation shall be carried out in accordance with the following procedures:
- (4.1) Establish a gas chromatograph as follows:
- Temperature of column tank at 200°C
- Temperature of sample induction part at 250°C
- Flow rate of carrier gas at 40 ml/min
- Delivery speed of recording paper at 1 cm/min
- (4.2) Respectively put 40 ml absorption solution into two absorption bottles. After cooling the absorption bottles with ice, open the purge valve and sufficiently displace the inside of piping with sample gas.
- (4.3) Pass the sample gas through the absorption bottles at a flow rate given in Table 8 according to the content of naphthalene so that 3 to 30 mg naphthalene amount is absorbed in the case of using the heat conductivity type detector and 0.3 mg min. in the case of using the hydrogen flame ionization type detector to prepare the sample solution. Read the gas meter and calculate the volume of sample gas taken in accordance with 4.5.

Table 8. Relation between concentration of naphthalene and flow rate

Naphthalene content g/m ³	Flow rate l/h
Less than 0.5	60
0.5 min.	30

- (4.4) Transfer the sample solution in the first absorption bottle into a measuring cylinder with ground stopper (50 ml), wash the absorption bottle with a small amount of toluene and join washings thereto. Thereafter, accurately add the inner standard material solution containing *n*-heptadecane of 0.2 to 5 times the estimate naphthalene amount in the sample solution with a measuring pipette, then add toluene up to the mark and sufficiently mix them.
- (4.5) Introduce 5 μ l of this solution into the gas chromatograph with a micro syringe and obtain the peak area ratio of naphthalene to *n*-heptadecane from the obtained chromatogram.
- (4.6) Operate the sample solution in the second absorption bottle in the same way as in (4.4) and (4.5) and confirm no presence of naphthalene. If naphthalene is detected, obtain the peak area ratio in the same way as in (4.5).
- (5) Calculation Obtain the mass ratio of naphthalene amount to *n*-heptadecane amount from the working curve prepared in (6) concerning the area ratio obtained in (4.5) and calculate the concentration of naphthalene in sample gas from the following formula. If naphthalene is detected in the sample solution in the second absorption bottle in (4.6), calculate the concentration of naphthalene in the same calculation and add it to the concentration of naphthalene of the first absorption bottle.

$$C_{\text{NAPH}} = \frac{r \times w \times 1000}{V_0}$$

where, C_{NAPH} : concentration of naphthalene in sample gas (g/m^3)

r : mass ratio of naphthalene amount to *n*-heptadecane amount obtained from working curve

w : mass of *n*-heptadecane added to sample solution for analysis (g)

V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (1)

- (6) Preparation of working curve Prepare three measuring flasks (50 ml) and accurately add with a measuring pipet to each of them the inner standard material solution by the amount equal to the amount added in (4.4) and standard naphthalene solution by the amount equivalent to about 0.2, 2, and 5 times that amount (when the sampling amount decreases, each of them is diluted 10 times to be sampled) thereto. Thereafter, add toluene up to the mark. Operate those solutions in the same way as in (4.5) and prepare the relation curve between the peak area ratio of the obtained naphthalene to *n*-heptadecane and the mass ratio of naphthalene amount to *n*-heptadecane amount in accordance with 8.7 (Inner standard method) of JIS K 0114 to be the working curve.
- (7) Expression of analysis result Express the analysis result by rounding off to two significant numerals according to JIS Z 8401.

6.6 Method for chemical analysis of water content

6.6.1 Absorption weighing method

(1) Summary Water content is absorbed by passing the sample gas through absorption tube filled with magnesium perchlorate and its mass increase is measured. When 100 l of the sample gas is taken, the gas of 1.0 g/m³ min. in water content concentration can be analyzed by this method.

(2) Apparatus The apparatus shall be as follows:

(2.1) Absorption apparatus An example of absorption apparatus is given in Fig. 33. As for the absorption tube, the water content absorption tube given in Fig. 34 or the U-shaped tube given in Attached Fig. 49 of JIS R 3503 are used, the inside of which is filled with magnesium perchlorate, and three tubes are connected in series. At that time, A and B among the three absorption tubes are arranged so as to pass the sample gas through the absorption tube from upper side and C is arranged so as to pass the sample gas therethrough from lower side. As for the connection parts, the tubes of material having no water absorption property like silicone rubber or the like are used. As for the scrubbing bottle, the scrubbing bottle given in Attached Fig. 48 of JIS R 3503 is used.

Fig. 33. Water content absorption apparatus (An example)

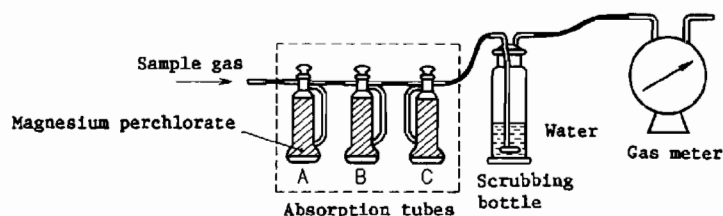
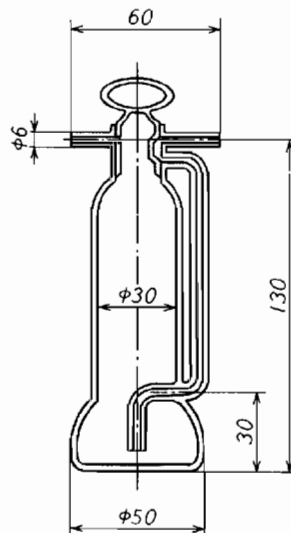


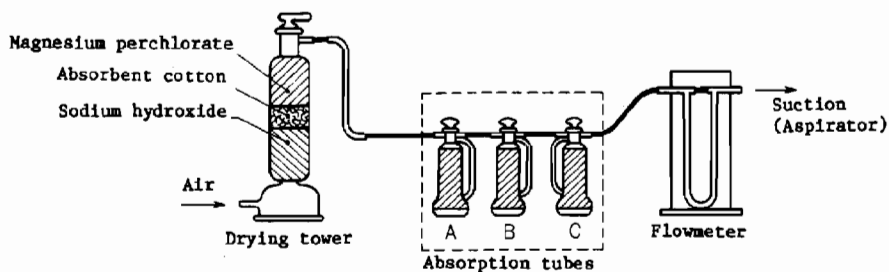
Fig. 34. Water content absorption tube (An example)



Unit: mm

- (2.2) Drying tower The drying tower given in Attached Fig. 69 of JIS R 3503 is used. The lower half of the inside thereof is filled with granular sodium hydroxide and the remaining part is filled with magnesium perchlorate as given in Fig. 35.
- (2.3) Chemical balance The chemical balance of 100 to 200 g in weighing capacity and 1 mg in reciprocal sensibility.
- (3) Reagents The reagents shall be as follows:
- (3.1) Magnesium perchlorate Magnesium perchlorate specified in JIS K 8228 for chemical analysis of elements. It is tightly stoppered and stored in a cold place.
- (3.2) Sodium hydroxide Granular sodium hydroxide specified in JIS K 8576.
- (4) Operation The operation shall be carried out in accordance with the following procedures:
- (4.1) Connect three absorption tubes as given in Fig. 35, pass air at a flow rate of about 0.2 l/min by sucking it with an aspirator for 10 min and displace the inside of absorption tubes with dry air. When the amounts of water content, carbon dioxide, etc. are little in the sample gas and the mass change of (4.2) has been confirmed to be able to be neglected, allow the inside of absorption tube to be displaced with the sample gas to be analyzed instead of air.

Fig. 35. Air displacement apparatus (An example)



- (4.2) After closing the cocks of absorption tubes, remove the absorption tubes A and B, measure the mass thereof to the nearest 0.1 mg and repeat the operation of (4.1) until the mass change reaches less than 1 mg. When the mass is measured, clean the outside of absorption tube by sufficiently wiping it with gauze and sufficiently discharge frictional static electricity generated on the surface. Thereafter, necessarily stabilize it in the balance chamber for awhile. The operation of making the absorption tube a constant weight is required only for the first measurement in the day and not for the second measurement and after.
- (4.3) Connect absorption tubes A, B and C as given in Fig. 33 and pass the sample gas at a flow rate of about 1.3 l/min so that the increased amount of water content becomes about 0.1 g. Read the gas meter and calculate the volume of sample gas taken in accordance with 4.5.
- (4.4) Close the cock leaving the absorption tubes A, B and C connected, remove them, connect the apparatus as given in Fig. 35 and carry out the operation of (4.1), again. However, when the inside of absorption tube is displaced with the sample gas instead of air in (4.1), do not carry out this operation.
- (4.5) Close the cocks of absorption tubes, remove the absorption tubes A and B, measure the mass thereof to the nearest 0.1 mg and obtain the mass increase before and after passing of sample gas.
- (5) Calculation The concentration of water content in sample gas shall be calculated from the following formula:

$$C_{H_2O} = \frac{w}{V_0} \times 1000$$

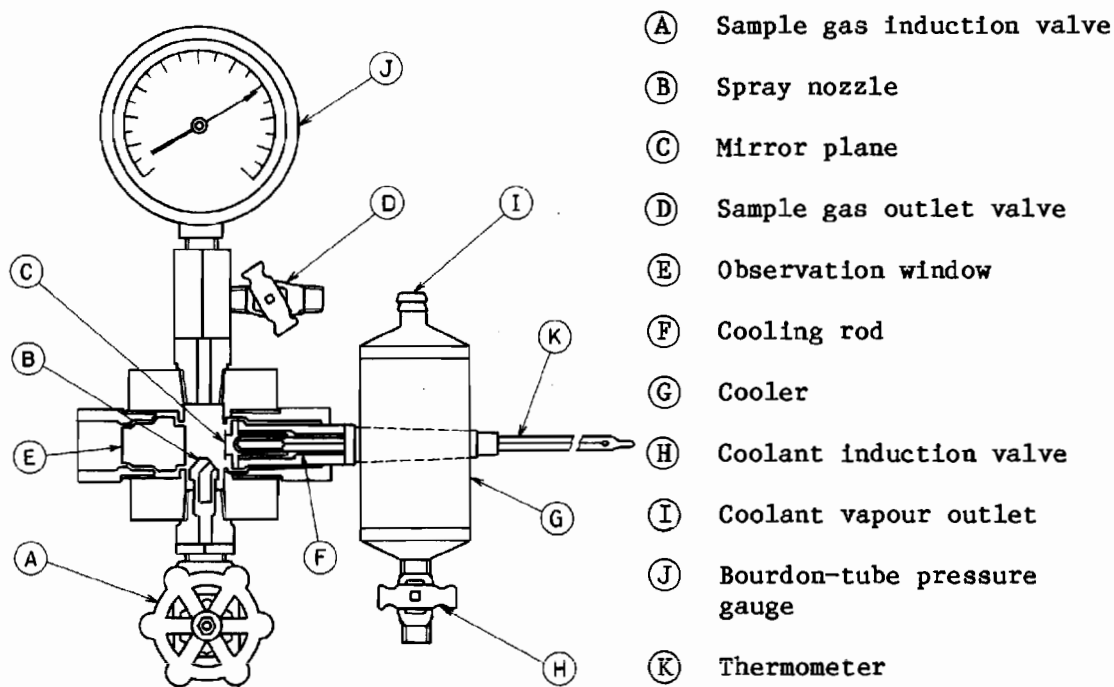
where, C_{H_2O} : concentration of water content in sample gas (g/m³)
 w : total amount of mass increase of absorption tubes A and B (g)
 V_0 : volume of sample gas in standard condition calculated in accordance with 4.5 (l)

- (6) Expression of analysis result Express the analysis result by rounding off to two significant numerals according to JIS Z 8401.

6.6.2 Dew point method

- (1) Summary The sample gas is passed through the dew point meter having a pressure gauge, a thermometer and the mirror plane on which steam is condensed, and the temperature of its dew point is read while gradually cooling it. The concentration of water content in sample gas in standard condition is obtained. This method is principally applied to the determination of the water content of natural gas at a high pressure.
- (2) Apparatus The apparatus shall be as follows:
- (2.1) Dew point meter The dew point meter is American Bureau of Mines type dew point meter given in Fig. 36 or a dew point meter having performance equal or superior thereto.

Fig. 36. American Bureau of Mines type dew point meter
(An example)



- (2.2) Thermometer The thermometer capable of being inserted into the thermometer hole of dew point meter, such as the bar-type mercury thermometer of -30 to $+50^{\circ}\text{C}$ in scale range and 0.5°C in scale interval.
- (2.3) Pressure gauge It is the pressure gauge of Grade 1.5, 25 to 0 MPa {250 to 0 kgf/cm²} in pressure range, 50 mm in size and 25 in division number, or otherwise that of 1 to 0 MPa {10 to 0 kgf/cm²} in pressure range, 50 mm in size and 20 in division number specified in Table 10 of JIS B 7505 according to the pressure when the sample gas is measured.

- (3) Coolant It is liquefied carbonic acid or liquefied petroleum gas.
- (4) Operation The operation shall be carried out in accordance with the following procedures:
- (4.1) Connect the sample gas duct to the sample gas induction valve (A) of dew point meter. At that time, the sample gas duct shall be necessarily kept at 2°C higher than the dew point of sample gas.
 - (4.2) Connect the outlet of coolant vessel to the coolant induction valve (H) of dew point meter with making the outlet downward.
 - (4.3) Open the sample gas induction valve (A) and induce the sample gas into the apparatus at a flow rate of about 1.4 to 14 l/min. Keep the flow rate of sample gas and the pressure in the apparatus constant by regulating the sample gas induction valve (A) and the sample gas outlet valve (D) and read the scale of the pressure gauge at that time.
 - (4.4) At times open the coolant induction valve (H), gasify coolant by inducting it into the cooler (G) and gradually cool the mirror plane (C) with the cooling rod (F). When an estimated dew point temperature is approached, regulate the cooling speed at not more than 0.5°C per minute.
 - (4.5) Observe the mirror plane and read the temperature at which cloudiness is generated with a thermometer. Because hydrogen carbide is sometimes condensed on the mirror plane before and after condensation of steam thereon at that time, therefore, care must be taken not to mistake viewing the phenomena.
 - (4.6) Regulate the opening and closing of coolant induction valve (H), raise a temperature by the same degree as that of cooling speed and read the temperature at which the cloudiness of mirror plane disappears.
 - (4.7) Repeat the operations of (4.4) to (4.6) 2 to 3 times and mean the temperatures read in (4.5) and (4.6) to be the dew point of sample gas at that pressure.
- (5) Calculation The water content shall be obtained from the dew point and the pressure of sample gas in accordance with Table 9 or Table 10.
- (6) Expression of analysis result Express the analysis result by rounding off to two significant numerals according to JIS Z 8401.

Table 9. Moisture conversion table by dew point method (1)

Unit: g/m³

Dew point (°C)	Pressure (kPa)																			
	101.2	294.2	490.3	686.4	980.6	1471	1961	2452	2942	3432	3922	4903	5884	6864	7845	8825	9806	11767	13728	15690
-40	0.15	.056	.035	.026	.019	.014	.012	.011	.010											
-38	0.19	.068	.042	.032	.023	.017	.014	.012	.011	.010										
-36	0.23	.083	.052	.038	.028	.021	.017	.014	.013	.012	.011	.010								
-34	0.29	0.10	.063	.047	.035	.025	.020	.017	.015	.014	.013	.012	.011	.010						
-32	0.34	0.12	.076	.057	.041	.029	.024	.020	.018	.016	.015	.014	.013	.012	.011	.010				
-30	0.41	0.14	.091	.068	.049	.035	.029	.024	.022	.020	.018	.016	.015	.014	.013	.012	.011	.010		
-28	0.50	0.18	0.11	.080	.059	.042	.034	.028	.026	.024	.021	.019	.017	.016	.015	.014	.014	.013	.012	.011
-26	0.60	0.21	0.13	0.10	.071	.050	.040	.034	.030	.027	.025	.022	.020	.018	.017	.016	.016	.015	.014	.013
-24	0.72	0.25	0.16	0.12	.084	.060	.048	.040	.036	.032	.029	.026	.023	.022	.020	.019	.018	.017	.016	.015
-22	0.86	0.30	0.19	0.14	.099	.070	.056	.047	.042	.038	.034	.030	.027	.025	.023	.022	.021	.020	.019	.018
-20	1.01	0.36	0.21	0.16	0.12	.080	.066	.056	.048	.044	.040	.035	.032	.028	.027	.026	.025	.023	.022	.021
-19	1.10	0.39	0.23	0.17	0.13	.088	.071	.060	.052	.047	.043	.037	.034	.031	.029	.028	.026	.024	.023	.022
-18	1.20	0.42	0.25	0.18	0.14	.097	.077	.065	.056	.051	.046	.040	.036	.033	.031	.030	.028	.026	.025	.024
-17	1.30	0.46	0.28	0.20	0.15	0.11	.083	.070	.061	.055	.050	.044	.039	.036	.034	.032	.030	.028	.027	.026
-16	1.42	0.50	0.30	0.22	0.16	0.11	.093	.076	.066	.059	.054	.047	.042	.039	.036	.034	.032	.030	.029	.028
-15	1.54	0.54	0.33	0.24	0.18	0.12	0.10	.082	.072	.064	.059	.051	.046	.042	.039	.037	.035	.032	.031	.029
-14	1.67	0.59	0.36	0.26	0.19	0.13	0.11	.088	.077	.069	.063	.055	.049	.045	.042	.039	.038	.035	.033	.031
-13	1.80	0.63	0.39	0.28	0.20	0.14	0.11	.095	.083	.074	.068	.058	.052	.048	.045	.042	.040	.037	.035	.033
-12	1.94	0.68	0.42	0.30	0.22	0.16	0.12	0.10	.089	.080	.073	.063	.056	.051	.048	.045	.043	.040	.037	.035
-11	2.10	0.74	0.45	0.33	0.24	0.17	0.13	0.11	.096	.086	.079	.067	.060	.055	.051	.048	.046	.042	.040	.038
-10	2.28	0.81	0.49	0.36	0.26	0.18	0.14	0.12	0.10	.093	.085	.072	.065	.059	.055	.052	.050	.046	.043	.041
-9	2.37	0.87	0.53	0.39	0.28	0.20	0.15	0.13	0.11	0.10	.091	.078	.070	.064	.059	.056	.053	.049	.046	.043
-8	2.67	0.94	0.58	0.42	0.30	0.21	0.17	0.14	0.12	0.11	.098	.084	.075	.068	.063	.060	.057	.052	.049	.046
-7	2.89	1.01	0.62	0.46	0.32	0.23	0.18	0.15	0.13	0.11	0.10	.090	.080	.073	.068	.064	.060	.055	.052	.049
-6	3.12	1.10	0.67	0.49	0.35	0.25	0.19	0.16	0.14	0.12	0.11	.096	.086	.078	.073	.068	.065	.059	.055	.053
-5	3.37	1.18	0.72	0.53	0.38	0.26	0.21	0.17	0.15	0.13	0.12	0.10	.092	.084	.078	.073	.069	.064	.059	.056
-4	3.56	1.27	0.78	0.57	0.41	0.28	0.22	0.18	0.16	0.14	0.13	0.11	.098	.089	.080	.078	.074	.067	.063	.060
-3	3.87	1.36	0.83	0.61	0.44	0.30	0.24	0.20	0.17	0.15	0.14	0.12	0.10	.090	.088	.082	.078	.071	.067	.063
-2	4.19	1.47	0.90	0.66	0.47	0.33	0.25	0.21	0.18	0.16	0.15	0.13	0.11	0.10	.093	.088	.083	.076	.071	.067
-1	4.53	1.58	0.96	0.70	0.50	0.35	0.27	0.23	0.20	0.17	0.16	0.13	0.12	0.11	0.10	.094	.089	.082	.076	.072
0	4.88	1.71	1.05	0.76	0.55	0.38	0.29	0.25	0.21	0.19	0.17	0.15	0.13	0.12	0.11	0.10	.095	.087	.081	.076
1	5.24	1.83	1.12	0.81	0.58	0.40	0.31	0.26	0.22	0.20	0.18	0.15	0.14	0.12	0.11	0.10	.091	.086	.080	.077
2	5.64	1.97	1.20	0.87	0.62	0.43	0.34	0.28	0.24	0.21	0.19	0.16	0.15	0.13	0.12	0.11	.098	.091	.086	.082
3	6.07	2.12	1.29	0.94	0.67	0.47	0.36	0.30	0.26	0.23	0.21	0.18	0.16	0.14	0.13	0.12	0.11	.097	.091	.087
4	6.52		1.38	1.00	0.72	0.50	0.39	0.32	0.28	0.24	0.22	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.10	.097
5	7.00		1.49	1.08	0.77	0.53	0.42	0.34	0.30	0.26	0.24	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.11	.098
6	7.48		1.59	1.15	0.83	0.57	0.44	0.37	0.32	0.28	0.25	0.21	0.19	0.17	0.16	0.15	0.14	0.12	0.12	.098
7	8.02		1.70	1.23	0.88	0.61	0.47	0.39	0.34	0.30	0.27	0.23	0.20	0.18	0.17	0.16	0.15	0.13	0.12	.099
8	8.56		1.83	1.32	0.95	0.65	0.51	0.42	0.36	0.32	0.29	0.24	0.21	0.19	0.18	0.17	0.16	0.14	0.13	.100
9	9.20		1.95	1.41	1.01	0.70	0.54	0.45	0.38	0.34	0.31	0.26	0.23	0.21	0.19	0.18	0.17	0.15	0.14	.101
10	9.80		2.09	1.50	1.08	0.75	0.58	0.48	0.41	0.36	0.33	0.28	0.24	0.22	0.20	0.19	0.18	0.16	0.15	.102
11	10.4			1.59	1.13	0.79	0.61	0.50	0.43	0.38	0.35	0.29	0.25	0.23	0.21	0.20	0.18	0.17	0.15	.103
12	11.1			1.69	1.20	0.83	0.64	0.53	0.45	0.40	0.37	0.31	0.27	0.24	0.22	0.21	0.19	0.17	0.16	.104
13	11.8			1.80	1.29	0.89	0.69	0.57	0.49	0.43	0.39	0.33	0.29	0.26	0.24	0.22	0.21	0.19	0.17	.105
14	12.6			1.93	1.39	0.96	0.74	0.61	0.52	0.46	0.41	0.35	0.31	0.27	0.25	0.23	0.22	0.20	0.18	.106
15	13.5			2.08	1.49	1.02	0.79	0.65	0.56	0.49	0.44	0.37	0.33	0.29	0.27	0.25	0.23	0.21	0.19	.107
16	14.4				1.58	1.09	0.84	0.69	0.59	0.52	0.47	0.40	0.35	0.31	0.28	0.26	0.25	0.22	0.21	.108
17	15.4				1.67	1.15	0.89	0.73	0.63	0.55	0.50	0.42	0.37	0.33	0.30	0.28	0.26	0.23	0.22	.109
18	16.4				1.79	1.23	0.95	0.78	0.67	0.59	0.53	0.44	0.39	0.35	0.32	0.29	0.28	0.25	0.23	.110
19	17.5				1.90	1.31	1.01	0.83	0.71	0.63	0.56	0.47	0.41	0.37	0.34	0.31	0.29	0.26	0.24	.111
20	18.6				2.04	1.40	1.08	0.89	0.76	0.66	0.59	0.50	0.44	0.39	0.36	0.33	0.31	0.28	0.26	.112
22	21.1					1.58	1.22	1.00	0.85	0.75	0.67	0.56	0.49	0.44	0.40	0.37	0.35	0.31	0.29	.113
25	25.3					1.88	1.45	1.19	1.01	0.89	0.79	0.67	0.58	0.52	0.47	0.44	0.41	0.37	0.34	.114

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Table 10. Moisture conversion table by dew point method (2)

Unit: g/m³

Dew point (°C)	Pressure (kgf/cm ²)																					
	1.033	3	5	7	10	15	20	25	30	35	40	50	60	70	80	90	100	120	140	160	180	200
-40	0.15	.056	.035	.026	.019	.014	.012	.011	.010													
-38	0.19	.068	.042	.032	.023	.017	.014	.012	.011	.010												
-36	0.23	.083	.052	.038	.028	.021	.017	.014	.013	.012	.011	.010										
-34	0.29	0.10	.063	.047	.035	.025	.020	.017	.015	.014	.013	.012	.011	.010								
-32	0.34	0.12	.076	.057	.041	.029	.024	.020	.018	.016	.015	.014	.013	.012	.011	.010						
-30	0.41	0.14	.091	.068	.049	.035	.029	.024	.022	.020	.018	.016	.015	.014	.013	.012	.012	.011	.010			
-28	0.50	0.18	0.11	.080	.059	.042	.034	.028	.026	.024	.021	.019	.017	.016	.015	.014	.014	.013	.012	.012	.011	
-26	0.60	0.21	0.13	0.10	.071	.050	.040	.034	.030	.027	.025	.022	.020	.018	.017	.016	.016	.015	.014	.014	.013	.013
-24	0.72	0.25	0.16	0.12	.084	.060	.048	.040	.036	.032	.029	.026	.023	.022	.020	.019	.018	.017	.016	.016	.015	.015
-22	0.86	0.30	0.19	0.14	.099	.070	.056	.047	.042	.038	.034	.030	.027	.025	.023	.022	.021	.020	.019	.018	.017	.017
-20	1.01	0.36	0.21	0.16	0.12	.080	.066	.056	.048	.044	.040	.035	.032	.028	.027	.026	.025	.023	.022	.021	.020	.019
-19	1.10	0.39	0.23	0.17	0.13	.088	.071	.060	.052	.047	.043	.037	.034	.031	.029	.028	.026	.024	.023	.022	.021	.021
-18	1.20	0.42	0.25	0.18	0.14	.097	.077	.065	.056	.051	.046	.040	.036	.033	.031	.030	.028	.026	.025	.024	.023	.022
-17	1.30	0.46	0.28	0.20	0.15	0.11	.083	.070	.061	.055	.050	.044	.039	.036	.034	.032	.030	.028	.027	.026	.025	.024
-16	1.42	0.50	0.30	0.22	0.16	0.11	.093	.076	.066	.059	.054	.047	.042	.039	.036	.034	.032	.030	.029	.027	.026	.025
-15	1.54	0.54	0.33	0.24	0.18	0.12	0.10	.082	.072	.064	.059	.051	.046	.042	.039	.037	.035	.032	.031	.029	.028	.027
-14	1.67	0.59	0.36	0.26	0.19	0.13	0.11	.088	.077	.069	.063	.055	.049	.045	.042	.039	.038	.035	.033	.031	.030	.029
-13	1.80	0.63	0.39	0.28	0.20	0.14	0.11	.095	.083	.074	.068	.058	.052	.048	.045	.042	.040	.037	.035	.033	.032	.031
-12	1.94	0.68	0.42	0.30	0.22	0.16	0.12	0.10	.089	.080	.073	.063	.056	.051	.048	.045	.043	.040	.037	.035	.034	.033
-11	2.10	0.74	0.45	0.33	0.24	0.17	0.13	0.11	.096	.086	.079	.067	.060	.055	.051	.048	.046	.042	.040	.038	.036	.035
-10	2.28	0.81	0.49	0.36	0.26	0.18	0.14	0.12	0.10	.093	.085	.072	.065	.059	.055	.052	.050	.046	.043	.041	.039	.038
-9	2.37	0.87	0.53	0.39	0.28	0.20	0.15	0.13	0.11	0.10	.091	.078	.070	.064	.059	.056	.053	.049	.046	.043	.042	.040
-8	2.67	0.94	0.58	0.42	0.30	0.21	0.17	0.14	0.12	0.11	.098	.084	.075	.068	.063	.060	.057	.052	.049	.046	.044	.043
-7	2.89	1.01	0.62	0.46	0.32	0.23	0.18	0.15	0.13	0.11	0.10	.090	.080	.073	.068	.064	.060	.055	.052	.049	.047	.046
-6	3.12	1.10	0.67	0.49	0.35	0.25	0.19	0.16	0.14	0.12	0.11	.096	.086	.078	.073	.068	.065	.059	.055	.053	.050	.049
-5	3.37	1.18	0.72	0.53	0.38	0.26	0.21	0.17	0.15	0.13	0.12	0.10	.092	.084	.078	.073	.069	.064	.059	.056	.054	.052
-4	3.56	1.27	0.78	0.57	0.41	0.28	0.22	0.18	0.16	0.14	0.13	0.11	.098	.089	.080	.078	.074	.067	.063	.060	.057	.055
-3	3.87	1.36	0.83	0.61	0.44	0.30	0.24	0.20	0.17	0.15	0.14	0.12	0.10	.090	.088	.082	.078	.071	.067	.063	.060	.058
-2	4.19	1.47	0.90	0.66	0.47	0.33	0.25	0.21	0.18	0.16	0.15	0.13	0.11	0.10	.093	.088	.083	.076	.071	.067	.064	.062
-1	4.53	1.58	0.96	0.70	0.50	0.35	0.27	0.23	0.20	0.17	0.16	0.13	0.12	0.11	0.10	.094	.089	.082	.076	.072	.068	.066
0	4.88	1.71	1.05	0.76	0.55	0.38	0.29	0.25	0.21	0.19	0.17	0.15	0.13	0.12	0.11	0.10	.095	.087	.081	.076	.073	.070
1	5.24	1.83	1.12	0.81	0.58	0.40	0.31	0.26	0.22	0.20	0.18	0.15	0.14	0.12	0.11	0.11	0.10	.091	.086	.080	.077	.074
2	5.64	1.97	1.20	0.87	0.62	0.43	0.34	0.28	0.24	0.21	0.19	0.16	0.15	0.13	0.12	0.11	0.11	.098	.091	.086	.082	.079
3	6.07	2.12	1.29	0.94	0.67	0.47	0.36	0.30	0.26	0.23	0.21	0.18	0.16	0.14	0.13	0.12	0.11	0.10	.097	.091	.087	.084
4	6.52		1.38	1.00	0.72	0.50	0.39	0.32	0.28	0.24	0.22	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.10	.097	.092	.089
5	7.00		1.49	1.08	0.77	0.53	0.42	0.34	0.30	0.26	0.24	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.11	0.10	.098	.094
6	7.48		1.59	1.15	0.83	0.57	0.44	0.37	0.32	0.28	0.25	0.21	0.19	0.17	0.16	0.15	0.14	0.12	0.12	0.11	0.10	0.10
7	8.02		1.70	1.23	0.88	0.61	0.47	0.39	0.34	0.30	0.27	0.23	0.20	0.18	0.17	0.16	0.15	0.13	0.12	0.12	0.11	0.11
8	8.56		1.83	1.32	0.95	0.65	0.51	0.42	0.36	0.32	0.29	0.24	0.21	0.19	0.18	0.17	0.16	0.14	0.13	0.12	0.12	0.11
9	9.20		1.95	1.41	1.01	0.70	0.54	0.45	0.38	0.34	0.31	0.26	0.23	0.21	0.19	0.18	0.17	0.15	0.14	0.13	0.12	0.12
10	9.80		2.09	1.50	1.08	0.75	0.58	0.48	0.41	0.36	0.33	0.28	0.24	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.13
11	10.4			1.59	1.13	0.79	0.61	0.50	0.43	0.38	0.35	0.29	0.25	0.23	0.21	0.20	0.18	0.17	0.15	0.14	0.14	0.13
12	11.1			1.69	1.20	0.83	0.64	0.53	0.45	0.40	0.37	0.31	0.27	0.24	0.22	0.21	0.19	0.17	0.16	0.15	0.14	0.14
13	11.8			1.80	1.29	0.89	0.69	0.57	0.49	0.43	0.39	0.33	0.29	0.26	0.24	0.22	0.21	0.19	0.17	0.16	0.15	0.15
14	12.6			1.93	1.39	0.96	0.74	0.61	0.52	0.46	0.41	0.35	0.31	0.27	0.25	0.23	0.22	0.20	0.18	0.17	0.16	0.16
15	13.5			2.08	1.49	1.02	0.79	0.65	0.56	0.49	0.44	0.37	0.33	0.29	0.27	0.25	0.23	0.21	0.19	0.18	0.17	0.17
16	14.4				1.58	1.09	0.84	0.69	0.59	0.52	0.47	0.40	0.35	0.31	0.28	0.26	0.25	0.22	0.21	0.19	0.18	0.17
17	15.4				1.67	1.15	0.89	0.73	0.63	0.55	0.50	0.42	0.37	0.33	0.30	0.28	0.26	0.23	0.22	0.20	0.19	0.18
18	16.4				1.79	1.23	0.95	0.78	0.67	0.59	0.53	0.44	0.39	0.35	0.32	0.29	0.28	0.25	0.23	0.21	0.20	0.19
19	17.5				1.90	1.31	1.01	0.83	0.71	0.63	0.56	0.47	0.41	0.37	0.34	0.31	0.29	0.26	0.24	0.22	0.21	0.20
20	18.6				2.04	1.40	1.08	0.89	0.76	0.66	0.59	0.50	0.44	0.39	0.36	0.33	0.31	0.28	0.26	0.24	0.23	0.22
22	21.1					1.58	1.22	1.00	0.85	0.75	0.67	0.56	0.49	0.44	0.40	0.37	0.35	0.31	0.29	0.27	0.25	0.24
25	25.3					1.88	1.45	1.19	1.01	0.89	0.79	0.67	0.58	0.52	0.47	0.44	0.41	0.37	0.34	0.31	0.29	0.28

7. Method for measurement of calorific value

7.1 Classification of methods for measurement of calorific value

The calorific value shall be measured by using a Junker's running water type gas calorimeter, or be attained by calculation from the constituent composition obtained according to 5.

7.2 Junker's running water type gas calorimeter method

7.2.1 Summary Sample gas is completely burned together with air. The combustion waste gas is cooled to the initial gas temperature and the generated steam is condensed. Total amount of generated heat is absorbed with water flowing through the calorimeter. Gross calorific value is obtained from the running water amount equivalent to a fixed sample gas amount and the difference between the temperatures of its running water at the inlet and the outlet. This method applies to the sample gas of about 8400 to 62800 kJ/m³{about 2000 to 15000 kcal/m³} in gross calorific value.

7.2.2 Measurement chamber The measurement chamber of calorific value shall conform to the following conditions:

- (1) The measurement apparatus of 7.2.3 can be functionally arranged.
- (2) The measurement apparatus shall not be exposed to the direct rays of the sun or otherwise to the radiant heat from other heat sources.
- (3) Windows and doors near the measurement apparatus shall be shut tightly and the temperature conditions in the room shall not be disturbed by a draught or the like.
- (4) In order to keep the measurement conditions of 7.2.4 (2) and (3), the temperature distribution in the room shall be kept uniformly by installing a suitable room temperature regulator as required, or otherwise with a rotary fan gently stirring the inside of chamber, or the like.
- (5) It shall be able to carry out suitable ventilation for the purpose of exhausting combustion waste gas.

7.2.3 Measurement apparatus The measurement apparatus shall be as follows and the arrangement thereof shall be as given in Fig. 37.

- (1) Gas calorimeter It is the gas calorimeter having the structure and dimensions given in Fig. 38.
- (2) Humidity control type air moistener It is the humidity control type air moistener having the structure and dimensions given in Fig. 39.

Further, in order to connect the humidity control type air moistener to the gas calorimeter, an adaptor as given in Fig. 40 may be used.

- (3) Gas meter It is the wet gas meter made of corrosion resisting material in which the drum is directly connected to the needle and all the front surface of which is made the needle plate, and the measuring capacity and the minimum scale thereof is as given in Table 11.

Table 11. Wet gas meter

Unit: l

One revolution passing amount	5
One hour passing amount	20 to 1500
Minimum scale	0.02

- (4) Gas pressure regulator It is the gas pressure regulator having the structure and dimensions given in Fig. 41, which can regulate the pressure of sample gas at least within a range of 0.20 to 0.59 kPa {20 to 60 mm H₂O} by the variation of weight.
- (5) Gas moistener It is the gas moistener having the structure and dimensions given in Fig. 42.

(6) Thermometer

- (6.1) Thermometer for measurement of flowing water temperature It is the double tube precise mercury thermometer made of glass as given in Table 12.

Further, two thermometers for flowing water inlet and for flowing water outlet and a gas calorimeter shall be used as unit group.

- (6.2) Other thermometers The thermometer for the gas meter, room-temperature measuring thermometer, thermometer for humidity controlling type air moistener (for dry bulb and wet bulb), thermometer for water temperature control, and a thermometer for calorimeter exhaust gas shall be double-tube glass or bar-type mercury thermometers as shown in Table 12.

Table 12. Thermometers

		Thermometer for measurement of flowing water temperature	Other thermometer
Scale range	°C	0 to 50	0 to 50
Scale interval	°C	0.1	0.2 or 0.5
Scale figures	°C	At intervals of 2	At intervals of 5 or 10
Overall length	mm	About 420	-
Diameter	mm	About 9	
Length of graduated portion	mm	About 280	
Diameter of mercury bulb	mm	About 7	
Length of mercury bulb	mm	About 20	

Remarks: Instead of the thermometer specified in 6.2 and 6.3, the electric measuring method specified in JIS Z 8710 may be used. In this case, the method shall have the accuracy equivalent or superior to respective thermometers, and the calibration indicated in JIS Z 8710 shall be carried out.

- (7) Balance Either one of the balances shown in Table 13.

Table 13. Balance

Weighing capacity kg	Reciprocal sensibility g
5	2 max.
10	5 max.

- (8) Barometer Fortin's barometer or the barometer having accuracy equivalent or superior thereto.
- (9) Water temperature controller By combination with the water bath, the controller is able to control at a level $2.0 \pm 0.5^{\circ}\text{C}$ lower than room temperature and to obtain water amount of about 2 to 3 l/min.

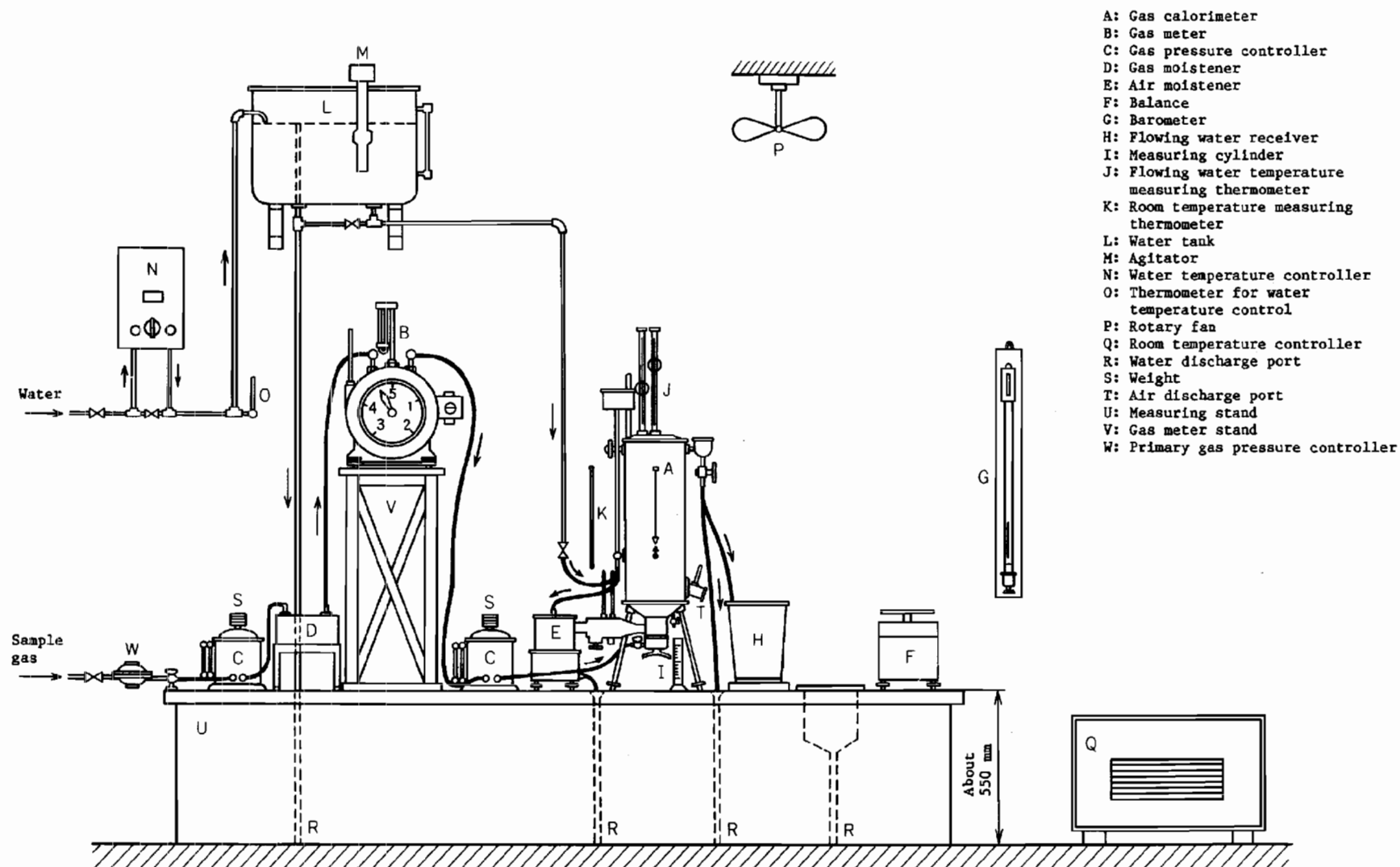
- (10) Flowing water receiver This receiver shall be made of a material providing good drainage in the shape shown in Fig. 37.
- (11) Measuring cylinder A plugless measuring cylinder as specified in JIS R 3505 with a capacity of 50 ml is used (for true calorific value calculation).

Remarks: The gas calorimeter, thermometer, gas meter, and balance satisfying the Measurement Law (Law No. 207 of 1951) shall be stored properly and be used with correction of instrumental error as required.

Further, also in the case of using the electric measuring method, the calibration capable of obtaining in accordance with this, as appropriate, shall be carried out.

Fig. 37. Arrangement of calorific value measuring apparatus (An example)

Unit: mm



- A: Gas calorimeter
- B: Gas meter
- C: Gas pressure controller
- D: Gas moistener
- E: Air moistener
- F: Balance
- G: Barometer
- H: Flowing water receiver
- I: Measuring cylinder
- J: Flowing water temperature measuring thermometer
- K: Room temperature measuring thermometer
- L: Water tank
- M: Agitator
- N: Water temperature controller
- O: Thermometer for water temperature control
- P: Rotary fan
- Q: Room temperature controller
- R: Water discharge port
- S: Weight
- T: Air discharge port
- U: Measuring stand
- V: Gas meter stand
- W: Primary gas pressure controller

Fig. 38. Gas calorimeter (An example)

Unit: mm

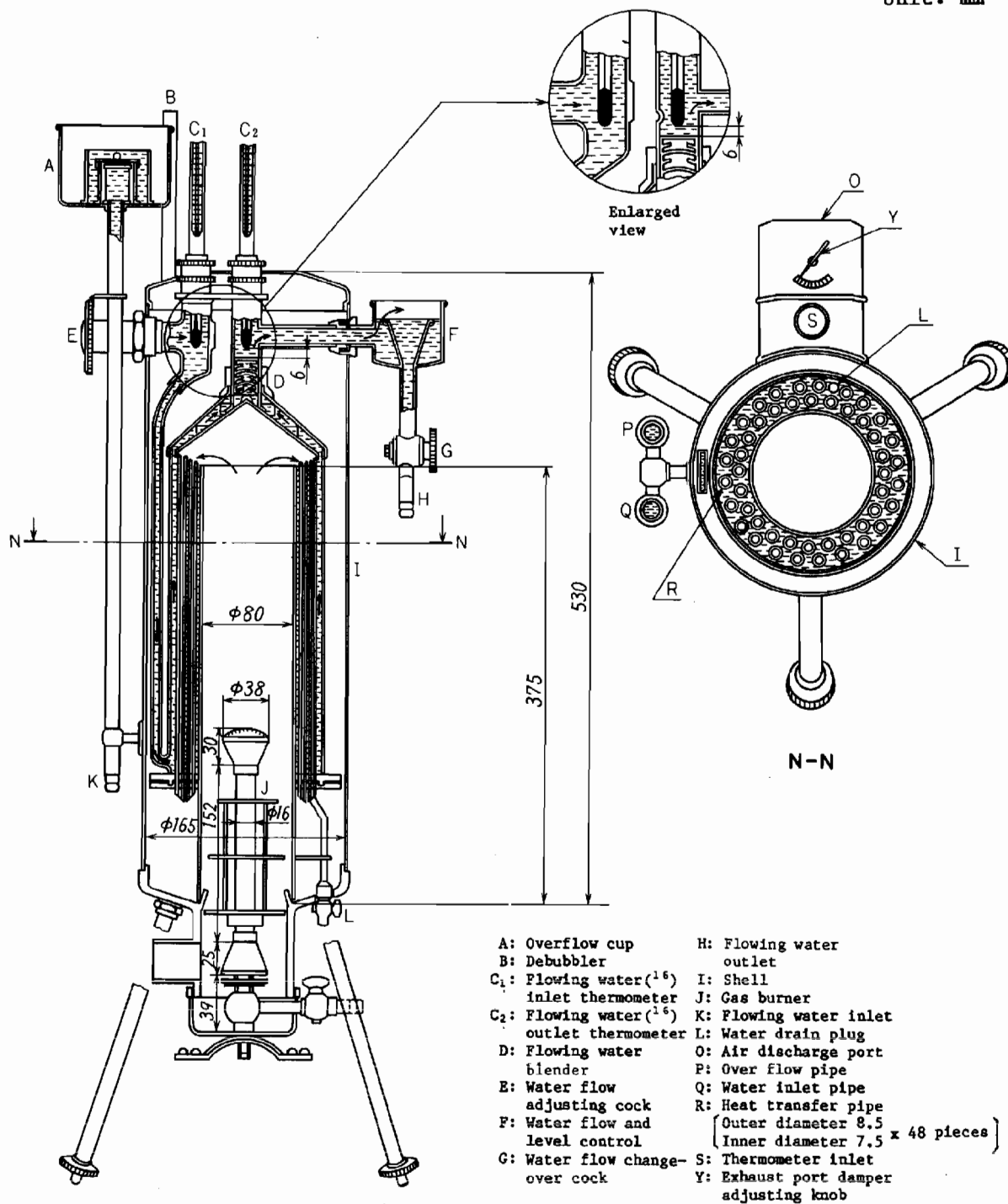
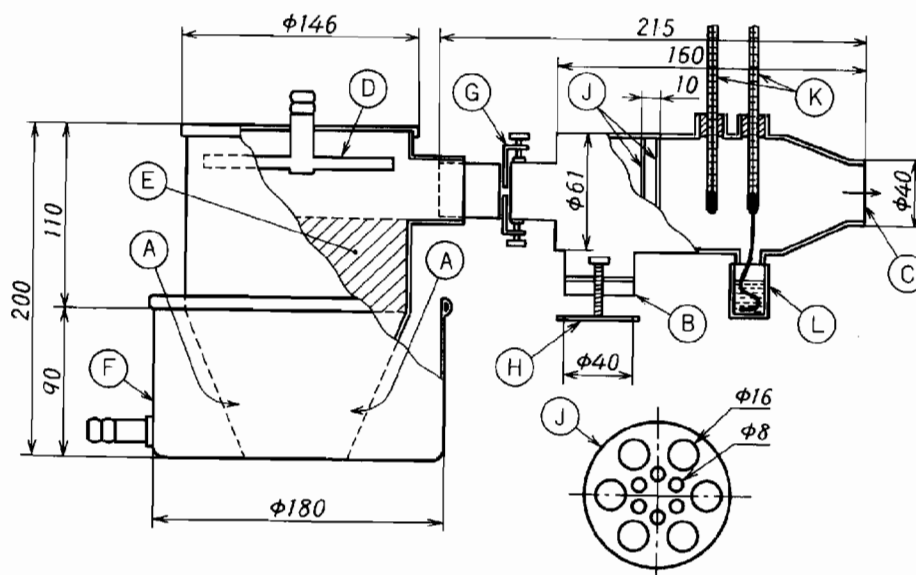


Fig. 39. Humidity control type air moistener (An Example)

Unit: mm



Mixing plate section figure

(Two sheet mixing plates are attached so as the holes to be alternative).

- | | |
|---|----------------------------------|
| Ⓐ : Air inlet | Ⓔ : Initial damper |
| Ⓑ : Air inlet for humidity control | Ⓕ : Secondary damper |
| Ⓒ : Wet air outlet (Calorimeter connection) | Ⓖ : Mixing plate |
| Ⓓ : Water-spray tube | Ⓚ : Wet-and-dry bulb thermometer |
| Ⓔ : Filling of $\phi 10$ Rasching ring | Ⓛ : Water pot |
| Ⓣ : Drain receiver | |

Fig. 40. Adaptor (An example)

Unit: mm

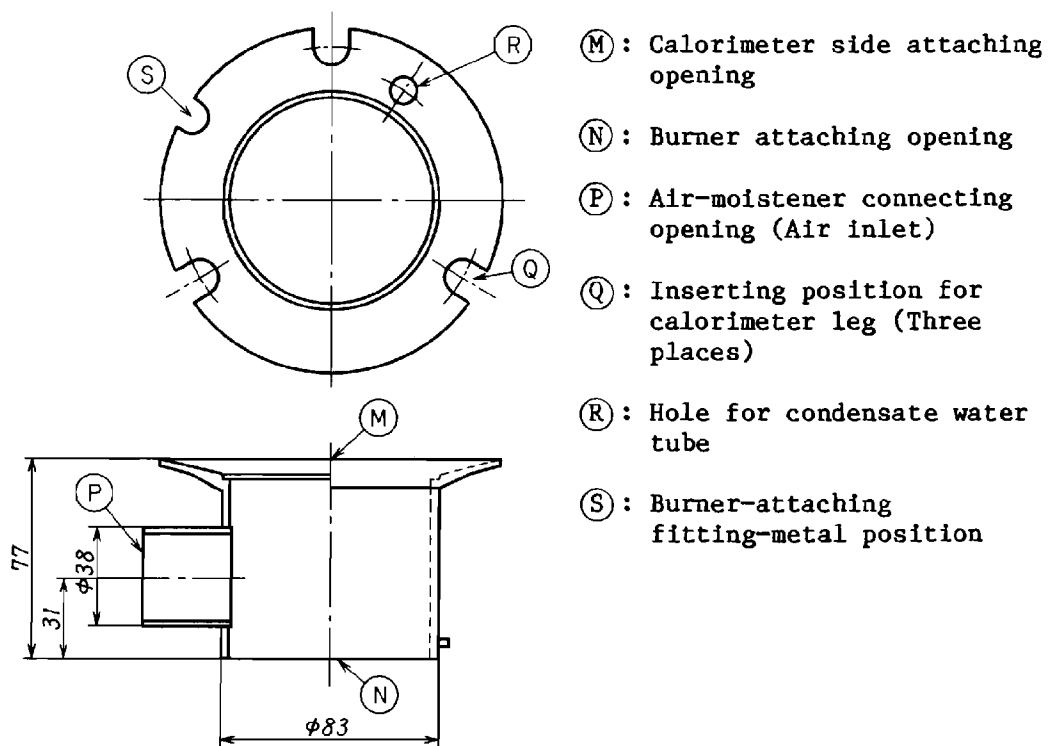


Fig. 41. Gas pressure regulator (An example)

Unit: mm

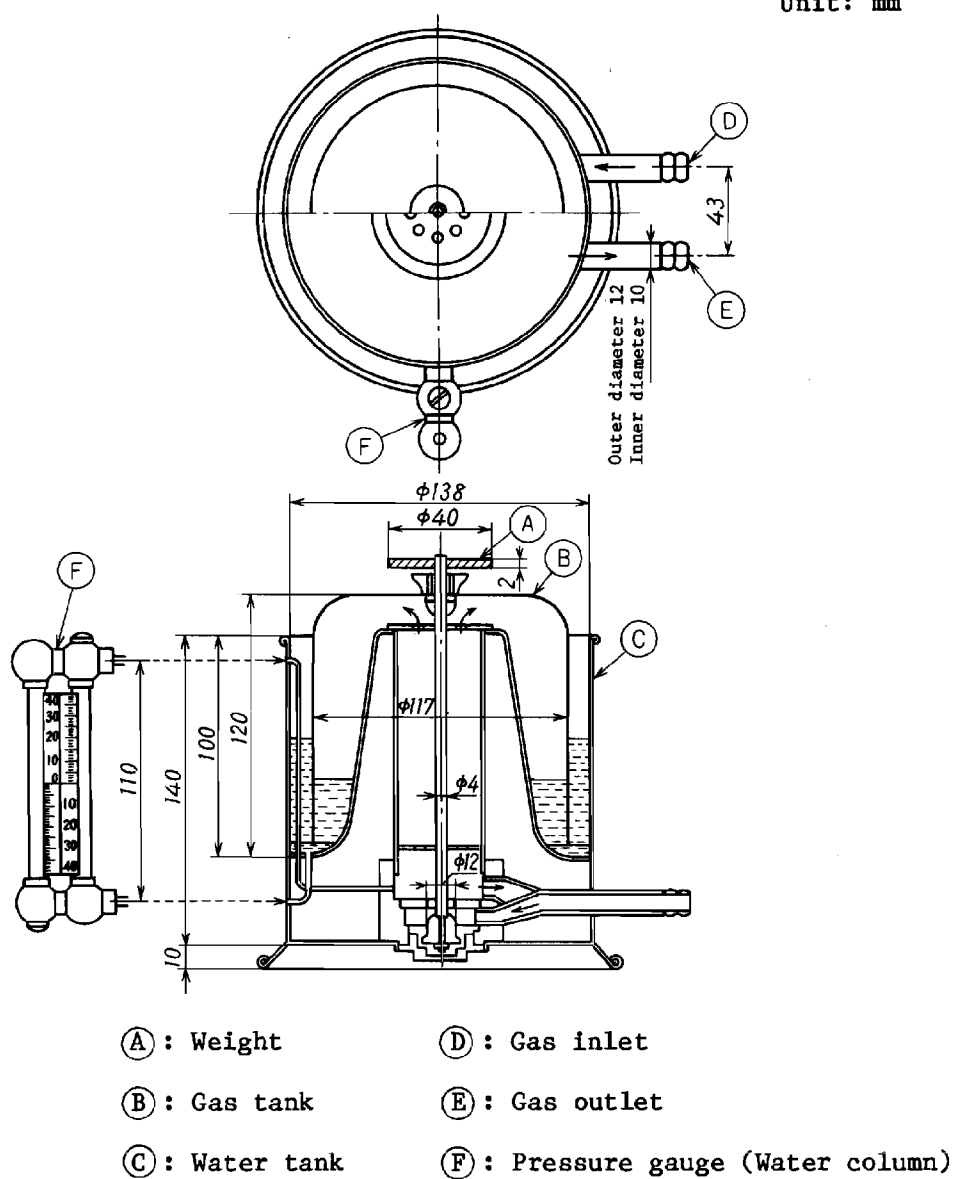
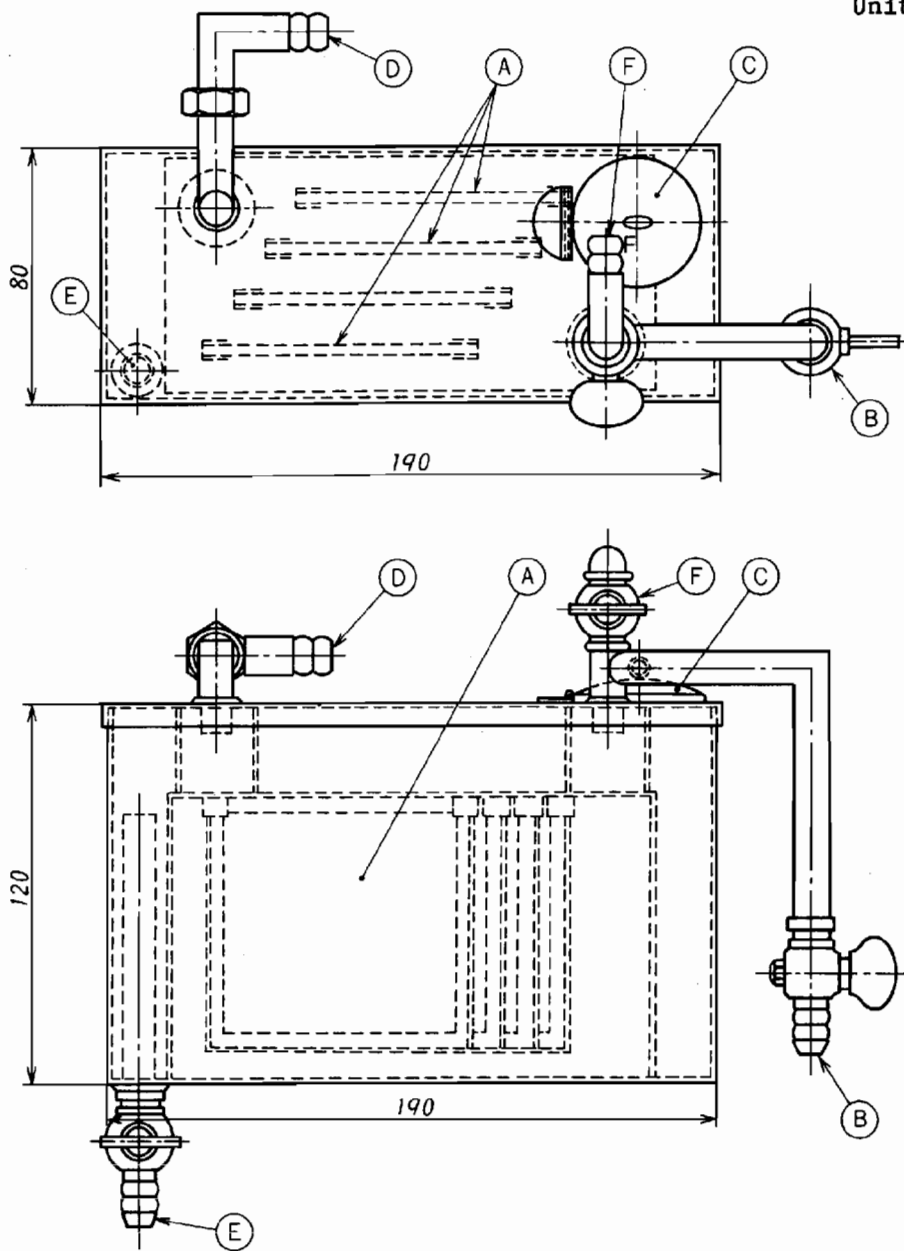


Fig. 42. Gas moistener (An example)

Unit: mm



- | | |
|---------------------------|--------------------------|
| Ⓐ : Gauze for moistening | Ⓓ : Gas outlet |
| Ⓑ : Gas inlet | Ⓔ : Water discharge port |
| Ⓒ : Water pouring opening | Ⓕ : Gas diffusion tube |

7.2.4 Method for measurement(1) Measuring conditions Measuring conditions shall be as follows:

- (1.1) The gross calorific value of the gas combusted in the gas calorimeter shall be within the range of 3800 to 4200 kJ { 900 to 1000 kcal } per hour.
- (1.2) The water temperature of the gas calorimeter and room temperature shall be kept within a range of $\pm 0.5^{\circ}\text{C}$ of each other.
- (1.3) The temperature of the water supplied to the gas calorimeter shall be kept at $2.0 \pm 0.5^{\circ}\text{C}$ lower than room temperature and the temperature fluctuation during measurement once should be maintained within 0.05°C as far as possible.
- (1.4) The flow rate of the water in the gas calorimeter shall be adjusted so that the temperature difference between the inlet and the outlet is kept at 10 to 12°C .
- (1.5) The humidity of the combustion air entering the gas calorimeter shall be adjusted to $80 \pm 5\%$.
- (1.6) The volume of the sample gas to be combusted in measurement once shall be as shown in Table 14.

Table 14. Sample gas volume

Total calorific value $\text{kJ}/\text{m}^3\{\text{kcal}/\text{m}^3\}$	Sample gas volume l
Less than 31400 {Less than 7500}	10
31400 or more {7500 or more}	5

(2) Preparation for measurement The preparation for measurement shall be carried out as follows:

- (2.1) Set the thermometers for flowing-water-temperature measurement to the gas calorimeter as shown in Fig. 38. Set the flowing water outlet thermometer so that the detecting element is at about 6 mm off the top end of the flowing water blender. Then set the gas calorimeter vertically on the measuring stand shown in Fig. 37, using the attached suspension type level.
- (2.2) Connect the air moistener to the gas calorimeter. Establish paths of the sample gas and water for the gas meter, gas moistener, gas pressure controller, etc., by connecting with rubber tubes as shown in Fig. 37. Displace the air in the gas route completely with the sample gas. Pay attention to the following points in installing each apparatus:

- (a) Each apparatus functions normally without gas or water leak.
 - (b) The gas meter is installed horizontally using the attached level. The pointer indicates the 5 l mark. The sealing water level is finely adjusted to the specified position with the gas inlet and outlet opened to the outside air.
 - (c) The sealing water levels in the gas moistener and gas pressure controller are at proper levels.
 - (d) The gauze of the wet-bulb thermometer of the air moistener is clean and always moistened by the water from the water pot.
 - (e) The room-temperature measuring thermometer is installed near the gas calorimeter as far as possible with its detecting element at the same level as the bottom of the gas calorimeter not to be exposed to the influence of the exhaust gas from the gas calorimeter.
 - (f) The sample gas route is applied with a sample gas pressure of about 0.78 kPa {80 mmH₂O}, with the gas burner cock closed, so as to preliminarily make sure that no gas is leaking.
- (2.3) Supply temperature-controlled water through the water tank to the gas calorimeter. Adjust the relationships between the room temperature, the flowing water inlet temperature and the gas meter water temperature to comply with the measuring conditions specified in 7.2.4 (1.2) and (1.3). Take the over-flowing amount of water always to the air moistener from the over-flow cup as the supply water amount to the gas calorimeter.
- (2.4) Attach the nozzle having a bore corresponding to the characteristics of the sample gas to gas burner, then ignite the gas burner and adjust the flow rate of sample gas conforming to measuring conditions in 7.2.4 (1.1)⁽¹⁷⁾.

Further, adjust the gas pressure so as to be in the range of 0.34 to 0.49 kPa {35 to 50 mmH₂O} in the gas meter by adjusting the weight of gas pressure controller.

Note ⁽¹⁷⁾ The combustion condition of gas burner varies according to the calorific value of the sample gas, specific gravity, amount of primary suction air and therefore, select the nozzle to obtain the adequate gas flow rate taking into reference Table 15 and adjust the gas pressure at the inlet of gas burner, as required.

Table 15. Relation between calorific value and flow rate of sample gas

Total calorific value of sample gas (approx.) kJ/m ³ (approx.) {kcal/m ³ }	Gas flow rate (approx.) l/h	(Informative reference) Example of burner nozzle inside diameter mm
62800 {15000}	65	1.0
54400 {13000}	75	1.0
46000 {11000}	90	1.0
37700 { 9000}	110	1.5
29300 { 7000}	140	2.0
21900 { 5000}	200	2.0
16700 { 4000}	250	2.0
12600 { 3000}	330	2.5
8400 { 2000}	500	4.0

- (2.5) Adjust the gas burner primary air flow to the level to cause quietly burning of outer and inner flames at the port with bright light appearing from time to time at the tip of the outer flame.

Then, fix the gas burner at the specified place in the gas calorimeter. At this time, fully open the damper at the gas calorimeter exhaust port.

- (2.6) Use the primary and secondary air dampers of the air moistener to adjust the humidity of the combustion air conforming to the measuring condition in 7.2.4 (1.5). Obtain the humidity of the combustion air from Attached Table 7 according to the readings of the attached wet-and-dry bulb thermometer 10 to 15 min after damper adjustment.
- (2.7) Adjust the supply water flow to gas calorimeter by the water flow adjusting cock. Hold the temperature difference between the inlet and outlet indicated by thermometers for flowing water temperature measuring to satisfy the condition in 7.2.4 (1.4).
- (2.8) Adjust the opening of the damper at the gas calorimeter exhaust port to keep the exhaust gas temperature at 0 to 0.5°C lower than room temperature and to maximize the temperature difference between the water inlet and the outlet. At this time, carefully prevent excessive closing of the damper.

- (2.9) Wet the inside of the flowing water receiver and measure the weight immediately after draining. Place it at the flowing water outlet of the gas calorimeter.

(3) Measuring operation The measuring operation shall be as follows:

- (3.1) Start measurement after confirming that the water outlet thermometer reading fluctuates within 0.2°C and condensed water dripping becomes uniform at least 10 min after fixing the gas burner in the gas calorimeter.
- (3.2) The moment when the gas meter pointer passes the proper graduation, quickly and surely set the water change-over cock of the gas calorimeter to the flowing water receiver side.
- (3.3) As the cock is switched, read the water inlet thermometer indication to 0.01°C by using the attached magnifying glass mercury thermometer and for other thermometer the temperature indicated on the indicator. Then, read the water outlet thermometer indication when the gas meter indication advances 0.5 l (or 0.25 l when the sample gas calorific value is 31400 kJ/m^3 { 7500 kcal/m^3 } or more, hereafter the same). Record the reading in the record table as shown in Informative reference Attached Table 1 or 2.
- (3.4) Thereafter, alternately read and record the indications at the water inlet and outlet thermometers each time where the gas meter pointer advances 0.5 l (or 0.25 l). At the moment when the gas meter pointer passes the starting position of graduation after 2 turns (or 1 turn), set the change-over cock to the discharge side.
- (3.5) When no water drips from the flowing water outlet, measure to record the mass of the water in the flowing water receiver to end one measurement.
- (3.6) Repeat successively the same measurement two more times and record the results of 3 measurements in total.
- (3.7) Further, carry out the following measurement quickly, and record the measured values and other necessary items on the record table:
- (a) Read out the sample gas temperature (water temperature of gas meter) to 0.1°C .
 - (b) Read out the sample gas pressure (pressure at gas meter) to 0.01 kPa { $1 \text{ mmH}_2\text{O}$ }.
 - (c) Read room temperature to 0.1°C .

- (d) Read the exhaust gas temperature of the gas calorimeter to 0.5°C.
- (e) Read the barometer indication to 0.013 kPa { 0.1 mmHg} and the attached thermometer indication to 0.5°C.

Remarks: To obtain the true calorific value, receive the condensed water dripping from the gas calorimeter by the measuring cylinder. Separately, keep burning the sample gas until the volume of the condensed water reaches at least 10 ml. Measure the corresponding sample gas volume and condensed water volume.

7.2.5 Calculation The calculation shall be as follows:

- (1) Conversion factor The conversion factor shall be calculated to 4 significant figures by the following formula.

$$F_1 = \left(\frac{273.15}{t_0 + 273.15} \times \frac{1}{P_0} \right) \times (B_0 + P - S) \times f_1 \times f_2$$

where, F_1 : conversion factor of calorific value

f_1 : correction coefficient for gas calorimeter⁽¹⁸⁾

See 4.5 for t_0 , P_0 , B_0 , P , S and f_2 .

Note ⁽¹⁸⁾ The correction coefficient for the gas calorimeter is obtained in the same way as in 7.2.4 using the pure gas with a known calorific value indicated in Attached Table 9. Overall correction coefficient (f) as the product of the gas calorimeter correction coefficient and gas meter correction coefficient ($f_1 \times f_2$) may be obtained and used.

- (2) Measured calorific value The water inlet and outlet temperatures measured in 7.2.4 (3) shall be averaged for each measurement. After performing the thermometer instrumental error correction⁽¹⁹⁾ and exposed part indication correction⁽²⁰⁾, obtain the temperature difference and calculate the measured calorific value by the following formula.

$$H_j = \frac{W \times t_d}{V} \times F_2 \qquad \left\{ H_j = \frac{W \times t_d}{V} \right\}$$

where, H_j : measured calorific value obtained by once measurement (kJ/m³) { H_j : measured calorific value (kcal/m³) }

W : mass of water flowing out from the gas calorimeter in once measurement (g)

t_d : average temperature difference between the water inlet and the outlet (after corrections for thermometer instrumental errors and exposed part indication errors) in once measurement (°C)

V : sample gas volume burned in measurement (10 l or 5 l) once

F_2 : 4.18605 (conversion factor from kcal to kJ)

Notes (¹⁹) The thermometer instrumental error correction value (δ) of double tube mercury thermometer made of glass or bar mercury thermometer is obtained by the method in Annex of JIS B 7410 to be used, using the standard thermometer. However, in the case where the electric measuring method is used, that performed with the attaining possible calibration indicated in JIS Z 8710 is to be used.

(²⁰) Obtain the thermometer exposed part indication correction value (θ) according to Attached Table 8.

- (3) Handling of measured values If the measured calorific values as a result of 3 successive measurements by the same person do not satisfy the following formula, reject the values and carry out measurement again.

$$\frac{H_{\max} - H_{\min}}{\sum_{i=1}^3 \frac{H_i}{3}} \leq 0.010$$

where, H_{\max} : maximum values of measured calorific value

H_{\min} : minimum value of measured calorific value

- (4) Total calorific value calculation The total calorific value shall be calculated according to the following formula.

$$H_G = \frac{\sum H_i}{n} \times \frac{1}{F_1}$$

where, H_G : total calorific value (kJ/m³){kcal/m³}

$\sum H_i$: total of measured calorific values (3 times)
(kJ/m³){kcal/m³}

n : number of measurements (3 times)

Remarks: In the case of obtaining true calorific value calculate the true calorific value from the total calorific value and the volume of condensed water according to the following formula.

$$H_N = H_G - \left(\frac{L \times W_C \times 1000}{V_0} \right)$$

where, H_N : true calorific value of dry gas in standard condition (kJ/m³){kcal/m³}

L : latent heat of condensed water (2.5 kJ/g){0.6 kcal/g}

V_0 : volume of combusted gas for measurement of condensed water volume, converted by 4.5 (l)

W_C : condensed water volume resulting from combustion of V_0 (l) (ml)

7.2.6 Expression of measurement result The total calorific value shall be marked by rounding off to the places of 10 according to JIS Z 8401 and the measuring method, appended.

7.3 Method for obtaining by calculation

7.3.1 Summary The calorific value of sample gas is obtained by using the component composition obtained by 5. and the calorific values of respective components according to calculation.

7.3.2 Calculation The calculation of total calorific value shall be in accordance with the following formulae.

$$H_G = \frac{\sum C_{Mi} H_i}{Z}$$

$$Z = 1 - (\sum C_{Mi} \sqrt{b_i})^2 + 0.0005(2C_{MH} - C_{MH}^2)$$

$$b_i = 1 - Z_i$$

where, H_G : total calorific value of sample gas (kJ/m³){kcal/m³}
 C_{Mi} : mol content rate⁽²¹⁾ of component i
 H_i : total calorific value in the ideal condition of component i (kJ/m³) {kcal/m³}⁽²²⁾
 Z : compression coefficient of sample gas
 Z_i : compression coefficient of component i ⁽²²⁾
 $\sqrt{b_i}$: compression addition coefficient of component i
 C_{MH} : mol content rate of hydrogen in sample gas⁽²¹⁾

Notes ⁽²¹⁾ Obtain to four places of decimals.

⁽²²⁾ Obtain from Table 16.

Further, in the case of conversion to mol content rate from volume percentage (vol %), use the following formula.

$$C_{Mi} = \frac{\frac{C_{Vi}}{Z_i}}{\sum \frac{C_{Vi}}{Z_i}}$$

where, C_{Vi} : volume percentage of component i (vol %)
 C_{Mi} : mol content rate of component i
 Z_i : compression coefficient of component i

Remarks 1. In the case where the sum is expressed as series, calculate by using the calorific value and compression coefficient of representative component out of components contained therein.

2. In the case where the high-boiling-point hydrocarbon not less than C_6 is determined integrally as C_6^+ by using backflashing operation according to Remarks 3. of 5.2, when paraffins are main components represent by hexane and when aromatic hydrocarbons are main components represent by benzene to calculate.
3. In the case of obtaining the true calorific value, instead of total calorific value of Table 16, use the true calorific value and carry out the similar calculation.
4. In the case of natural gas and where the fact that there is no difference practically interferent to calculation result is confirmed and further the agreement between the parties concerned with delivery is performed, the calorific value may be calculated according to the following formula.

$$H_G = \sum \left(H_{vi} \frac{C_{vi}}{100} \right)$$

where, H_G : total calorific value of sample gas (kJ/m^3)
 $\{\text{kcal/m}^3\}$

C_{vi} : volume percentage of component i (vol %)

H_{vi} : total calorific value in the actually existing condition of component i (kJ/m^3) $\{\text{kcal/m}^3\}$

The calorific values in actually existing condition of pure gas to be used for this calculation are shown in Attached Table 9.

Informative reference: In the case of obtaining Z and H_G , refer to Informative reference Attached Table 3.

7.3.3 Expression of calculation result The calorific value shall be rounded off to the place of 10 according to JIS Z 8401 to mark and append the measuring method.

Table 16. Compression coefficients of pure gases, calorific values and specific gravities in the ideal condition

No.	Component	Molecular formula	Compression coefficient	Total calorific value (kJ/m ³){kcal/m ³ }	True calorific value (kJ/m ³){kcal/m ³ }	Specific gravity (Air = 1)
1	Hydrogen	H ₂	1.000 6	12 790 { 3 055 }	10 780 { 2 575 }	0.069 6
2	Oxygen	O ₂	0.999 0	—	—	1.104
3	Nitrogen	N ₂	0.999 5	—	—	0.967
4	Carbon monoxide	CO	0.999 4	12 600 { 3 010 }	12 600 { 3 010 }	0.967
5	Carbon dioxide ^(2 3)	CO ₂	0.995 5	—	—	1.519
6	Methane	CH ₄	0.997 5	39 840 { 9 517 }	35 820 { 8 557 }	0.554
7	Ethane	C ₂ H ₆	0.990 3	69 790 {16 670 }	63 760 {15 230 }	1.038
8	Ethylene	C ₂ H ₄	0.992 2	63 060 {15 060 }	59 050 {14 110 }	0.968
9	Propane	C ₃ H ₈	0.978 7	99 220 {23 700 }	91 180 {21 780 }	1.522
10	Propylene	C ₃ H ₆	0.981 1	91 960 {21 970 }	85 930 {20 530 }	1.452
11	Butane	C ₄ H ₁₀	0.957 7	128 600 {30 730 }	118 600 {28 330 }	2.006
12	Isobutane	C ₄ H ₁₀	0.963 6	128 200 {30 630 }	118 200 {28 230 }	2.006
13	1-Butene	C ₄ H ₈	0.961 6	121 400 {29 000 }	113 400 {27 090 }	1.936
14	Cis-2-butene	C ₄ H ₈	0.956 5	121 100 {28 930 }	113 100 {27 010 }	1.936
15	Trans-2-butene	C ₄ H ₈	0.957 8	120 900 {28 890 }	112 900 {26 970 }	1.936
16	Isobutene	C ₄ H ₈	0.961 5	120 700 {28 830 }	112 600 {26 910 }	1.936
17	1,3-Butadiene	C ₄ H ₆	0.965 3	113 500 {27 120 }	107 500 {25 680 }	1.866
18	Pentane	C ₅ H ₁₂	0.922 0	158 100 {37 760 }	146 000 {34 880 }	2.490
19	Isopentane	C ₅ H ₁₂	0.931 5	157 700 {37 680 }	145 700 {34 800 }	2.490
20	Neopentane	C ₅ H ₁₂	0.946 3	157 100 {37 530 }	145 100 {34 650 }	2.490
21	1-Pentene	C ₅ H ₁₀	0.931 8	150 800 {36 040 }	140 800 {33 640 }	2.420
22	Cis-2-pentene	C ₅ H ₁₀	0.929 7	150 600 {35 980 }	140 600 {33 580 }	2.420
23	Trans-2-pentene	C ₅ H ₁₀	0.929 7	150 400 {35 930 }	140 400 {33 530 }	2.420
24	2-Methyl-1-butene	C ₅ H ₁₀	0.935 5	150 200 {35 890 }	140 200 {33 490 }	2.420
25	3-Methyl-1-butene	C ₅ H ₁₀	0.941 0	150 500 {35 960 }	140 500 {33 570 }	2.420
26	2-Methyl-2-butene	C ₅ H ₁₀	0.934 2	150 000 {35 830 }	139 900 {33 430 }	2.420
27	Cyclopentane	C ₅ H ₁₀	0.932 1	148 400 {35 450 }	138 300 {33 050 }	2.420
28	Hexane	C ₆ H ₁₄	0.869 3	187 500 {44 800 }	173 500 {41 440 }	2.974
29	Isohexane	C ₆ H ₁₄	0.876 2	187 200 {44 710 }	173 100 {41 350 }	2.974
30	3-Methyl pentane	C ₆ H ₁₄	0.895 3	187 300 {44 740 }	173 200 {41 380 }	2.974
31	2,2-Dimethyl butane	C ₆ H ₁₄	0.884 4	186 700 {44 610 }	172 700 {41 250 }	2.974
32	2,3-Dimethyl butane	C ₆ H ₁₄	0.876 9	187 100 {44 690 }	173 000 {41 330 }	2.974
33	Benzene	C ₆ H ₆	0.902 9	147 500 {35 230 }	141 400 {33 790 }	2.695
34	Toluene	C ₇ H ₈	0.773 9	176 400 {42 130 }	168 300 {40 210 }	3.179

Note (2 3) The compression coefficient of carbon dioxide is the apparent value at low concentration.

8. Methods for specific gravity measurement

8.1 Classification of methods for specific gravity measurement

The specific gravity shall be measured by the Bunsen-Schilling method (effluence method) or pycnometer method, or be obtained by calculation from the composition of components obtained according to 5.

8.2 Bunsen-schilling's method (effluence method)

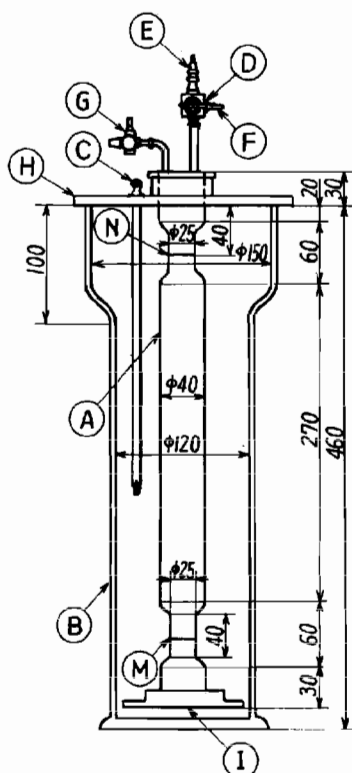
8.2.1 Summary Use the Bunsen-Schilling gravimeter and let sample gas and air flow out from the fine hole in the same operation. Calculate the specific gravity of the gas from the ratio of the effluence times required.

8.2.2 Apparatus The apparatus shall be as described below.

- (1) Bunsen-Schilling's gravimeter The structure and dimensions are as shown in Fig. 43, and the main parts are made of glass or transparent synthetic resin.
- (2) Thermometer The graduation range is 0 to 50°C with scale interval of 0.5°C. It is used to measure the temperature of the water in the outer cylinder of the Bunsen-Schilling's gravimeter.
- (3) Stop watch The stop watch capable of measuring to the nearest 0.1 s.

Fig. 43. Bunsen-Schilling gravimeter (An example)

Unit: mm



- (A) : Inner glass cylinder
- (B) : Outer glass cylinder
- (C) : Thermometer (inserted in metal protective tube)
- (D) : 3-way cock (orifice and gas outlet)
- (E) : Orifice [insertion of platinum plate (0.1 mm in thickness) having 0.3 mm in inner diameter bore true fine hole]
- (F) : Gas outlet
- (G) : Gas inlet
- (H) : Upper support frame (To be the structure to be supported at 3 points at the top of the outer glass cylinder)
- (I) : Lower support frame

Ⓜ, Ⓝ : Marks

Remarks: Each dimension in Figure shows the standard dimension.

8.2.3 Operation The operation shall be in accordance with the following procedures:

- (1) Fill water of room temperature in the outer cylinder of pycnometer.
- (2) Open the gas inlet cock, and move the internal cylinder up and down several times to replace inside of the internal cylinder with the room air. Then, raise the internal cylinder until the bottom metal portion is a little below the water surface. Close the gas inlet cock, and immerse the internal cylinder into the water to place at the specified position.
- (3) After standing as it is for 5 min, open the orifice side of the 3-way cock to let the air in the internal cylinder flow out through the fine hole of the platinum plate. Measure the time required for the water surface to travel between the top and bottom marks to 0.1 s (T_a).
- (4) Next, connect the gas inlet to the sample gas tube. Change over the 3-way cock to the gas outlet side. Open the gas inlet cock to let the sample gas flow into the internal cylinder. Move the internal cylinder up and down several times to replace the inside of the internal cylinder with the sample gas. Close the 3-way cock, raise the internal cylinder in the same way as in (2), close the gas inlet cock, and immerse the internal cylinder into the water to place at the specified position.
- (5) After allowing it to stand as it is for 5 min, measure the time required for the water surface to travel between the marks in the same way as in (3) (T_s).
- (6) Read out the water temperature on the thermometer to the accuracy of one graduation (0.5°C pitch).

8.2.4 Calculation Calculate the specific gravity of the dry sample gas relative to dry air according to the following formula.

$$S = \frac{T_s^2}{T_a^2} + \alpha$$

where, S: specific gravity of dry sample gas relative to dry air

T_s : sample gas outflow time (s)

T_a : air outflow time (s)

α : correction coefficient for conversion to specific gravity of dry gas (use Table 17).

8.2.5 Expression of measurement result The expression of measurement result shall be as given in the following:

- (1) As to measurement, carry out successively twice with repeating by the same person, confirm that the specific-gravity values of the two times' tests satisfy the tolerance 0.010, and when it is satisfied, obtain the mean value.
- (2) Express the measured value of specific gravity by rounding off to two places of decimals according to JIS Z 8401 and further append the measuring method.

8.3 Pycnometer method

8.3.1 Summary Fully charge each of the sample gas and dry air into the same pycnometer of a known mass. After adjustment of the temperature and pressure, weigh the pycnometer and calculate the specific gravity.

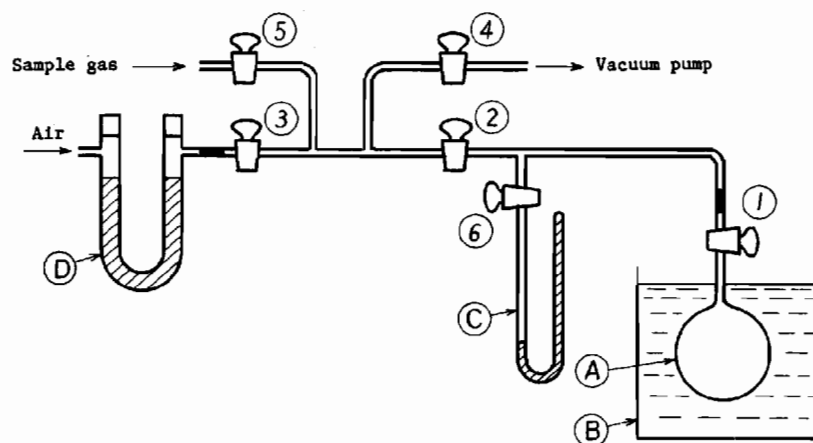
8.3.2 Apparatus The apparatus shall consist of the following components connected in arrangement as shown in Fig. 44.

- (1) Pycnometer The pycnometer made of hard glass having dimensions as shown in Fig. 45 (inside capacity: 100 to 300 ml).
- (2) Thermostatic water bath The thermostatic water bath capable of temperature adjustment in $\pm 0.05^{\circ}\text{C}$.
- (3) Vacuum pump The vacuum pump capable of pressure reduction to not more than (0.13 kPa) {1 mmHg}.
- (4) U-tube for air drying The U-tube shall be filled with silica gel.
- (5) Mercury manometer Closed-tube type mercury manometer allowing reading of vacuum pressure to 0.13 kPa {1 mmHg}.
- (6) Chemical balance The same one as 6.6.1 (2.3)

8.3.3 Operation The operation shall be in accordance with the following procedures:

- (1) Connect the pycnometer as shown in Fig. 44. Evacuate the inside of the pycnometer with the thermostatic water bath removed. Then, suck dry air to displace the inside of the pycnometer. Then again evacuate with a vacuum pump until the pressure in the pycnometer is reduced to 0.13 kPa {1 mmHg} or less. Close the pycnometer cock to disconnect and weigh its mass to the nearest 0.1 mg. Assume this mass to be W_0 . Before weighing, wipe the outside surface of the pycnometer to clean with gauze. After sufficient discharge of the friction static electricity on the surface, allow it to stand still in the balance room for some time.

Fig. 44. Arrangement figure of specific gravity measuring apparatus
(An example)



- (A): Pycnometer
 (B): Thermostatic water bath
 (C): Mercury manometer
 (D): U-tube for air drying
 (filled with silica gel)
 ① to ⑥: Operating cocks

Fig. 45. Pycnometer (An example)

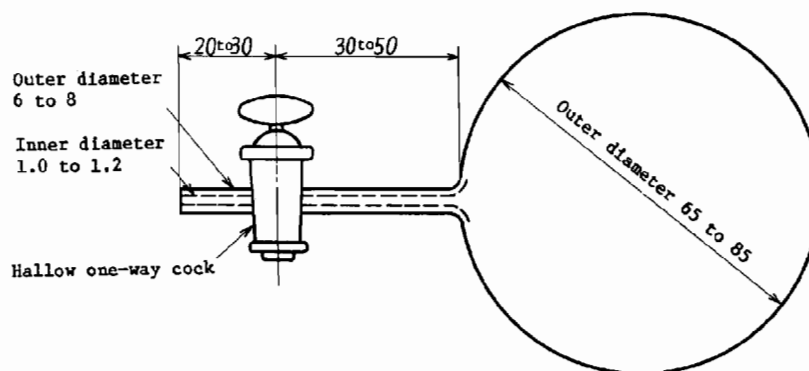


Table 17. Correction coefficient (α) for conversion of specific gravity of dry sample gas

Water temper- ature °C	$\frac{T_s^2}{T_a^2}$	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	$\frac{T_s^2}{T_a^2}$ Water temper- ature °C
1	-0.003	-0.002	-0.002	-0.002	-0.001	-0.001	-0.000	0	+0.000	+0.001	+0.001	+0.002	+0.002	+0.002	+0.002	+0.003	+0.003	+0.004	+0.004	1
2	-0.003	-0.003	-0.002	-0.002	-0.001	-0.001	-0.000	0	+0.000	+0.001	+0.001	+0.002	+0.002	+0.002	+0.003	+0.003	+0.003	+0.004	+0.004	2
3	-0.003	-0.003	-0.002	-0.002	-0.001	-0.001	-0.000	0	+0.000	+0.001	+0.001	+0.002	+0.002	+0.002	+0.003	+0.003	+0.004	+0.004	+0.005	3
4	-0.003	-0.003	-0.002	-0.002	-0.001	-0.001	-0.000	0	+0.000	+0.001	+0.001	+0.002	+0.002	+0.002	+0.003	+0.003	+0.004	+0.004	+0.005	4
5	-0.004	-0.003	-0.003	-0.002	-0.002	-0.001	-0.001	0	+0.001	+0.001	+0.002	+0.002	+0.003	+0.003	+0.003	+0.004	+0.004	+0.005	+0.005	5
6	-0.004	-0.003	-0.003	-0.002	-0.002	-0.001	-0.001	0	+0.001	+0.001	+0.002	+0.002	+0.003	+0.003	+0.003	+0.004	+0.004	+0.005	+0.006	6
7	-0.004	-0.004	-0.003	-0.002	-0.002	-0.001	-0.001	0	+0.001	+0.001	+0.002	+0.002	+0.003	+0.003	+0.004	+0.004	+0.005	+0.005	+0.006	7
8	-0.004	-0.004	-0.003	-0.003	-0.002	-0.001	-0.001	0	+0.001	+0.001	+0.002	+0.003	+0.003	+0.003	+0.004	+0.004	+0.005	+0.006	+0.006	8
9	-0.005	-0.004	-0.003	-0.003	-0.002	-0.001	-0.001	0	+0.001	+0.001	+0.002	+0.003	+0.003	+0.003	+0.004	+0.005	+0.005	+0.006	+0.007	9
10	-0.005	-0.004	-0.004	-0.003	-0.002	-0.001	-0.001	0	+0.001	+0.001	+0.002	+0.003	+0.004	+0.004	+0.004	+0.005	+0.006	+0.007	+0.007	10
11	-0.005	-0.005	-0.004	-0.003	-0.002	-0.002	-0.001	0	+0.001	+0.002	+0.002	+0.003	+0.004	+0.005	+0.005	+0.005	+0.006	+0.007	+0.008	11
12	-0.006	-0.005	-0.004	-0.003	-0.003	-0.002	-0.001	0	+0.001	+0.002	+0.003	+0.003	+0.004	+0.005	+0.005	+0.006	+0.007	+0.008	+0.008	12
13	-0.006	-0.005	-0.004	-0.004	-0.003	-0.002	-0.001	0	+0.001	+0.002	+0.003	+0.004	+0.004	+0.005	+0.006	+0.006	+0.007	+0.008	+0.009	13
14	-0.007	-0.006	-0.005	-0.004	-0.003	-0.002	-0.001	0	+0.001	+0.002	+0.003	+0.004	+0.005	+0.006	+0.006	+0.007	+0.008	+0.009	+0.010	14
15	-0.007	-0.006	-0.005	-0.004	-0.003	-0.002	-0.001	0	+0.001	+0.002	+0.003	+0.004	+0.005	+0.006	+0.006	+0.007	+0.008	+0.009	+0.010	15
16	-0.008	-0.007	-0.005	-0.004	-0.003	-0.002	-0.001	0	+0.001	+0.002	+0.003	+0.004	+0.005	+0.007	+0.007	+0.008	+0.009	+0.010	+0.011	16
17	-0.008	-0.007	-0.006	-0.005	-0.003	-0.002	-0.001	0	+0.001	+0.002	+0.003	+0.005	+0.006	+0.007	+0.007	+0.008	+0.009	+0.010	+0.012	17
18	-0.009	-0.007	-0.006	-0.005	-0.004	-0.002	-0.001	0	+0.001	+0.002	+0.004	+0.005	+0.006	+0.007	+0.007	+0.009	+0.010	+0.011	+0.012	18
19	-0.009	-0.008	-0.007	-0.005	-0.004	-0.003	-0.001	0	+0.001	+0.003	+0.004	+0.005	+0.007	+0.008	+0.008	+0.009	+0.011	+0.012	+0.013	19
20	-0.010	-0.009	-0.007	-0.006	-0.004	-0.003	-0.001	0	+0.001	+0.003	+0.004	+0.006	+0.007	+0.009	+0.009	+0.010	+0.011	+0.013	+0.014	20
21	-0.010	-0.009	-0.008	-0.006	-0.005	-0.003	-0.002	0	+0.002	+0.003	+0.005	+0.006	+0.008	+0.009	+0.010	+0.010	+0.012	+0.014	+0.015	21
22	-0.011	-0.010	-0.008	-0.006	-0.005	-0.003	-0.002	0	+0.002	+0.003	+0.005	+0.006	+0.008	+0.010	+0.010	+0.011	+0.013	+0.014	+0.016	22
23	-0.012	-0.010	-0.009	-0.007	-0.005	-0.003	-0.002	0	+0.002	+0.003	+0.005	+0.007	+0.009	+0.010	+0.010	+0.012	+0.014	+0.015	+0.017	23
24	-0.013	-0.011	-0.009	-0.007	-0.005	-0.004	-0.002	0	+0.002	+0.004	+0.005	+0.007	+0.009	+0.011	+0.011	+0.013	+0.014	+0.016	+0.018	24
25	-0.013	-0.012	-0.010	-0.008	-0.006	-0.004	-0.002	0	+0.002	+0.004	+0.006	+0.008	+0.010	+0.012	+0.012	+0.013	+0.015	+0.017	+0.019	25
26	-0.014	-0.012	-0.010	-0.008	-0.006	-0.004	-0.002	0	+0.002	+0.004	+0.006	+0.008	+0.010	+0.012	+0.012	+0.014	+0.016	+0.018	+0.020	26
27	-0.015	-0.013	-0.011	-0.009	-0.007	-0.004	-0.002	0	+0.002	+0.004	+0.007	+0.009	+0.011	+0.013	+0.013	+0.015	+0.017	+0.020	+0.022	27
28	-0.016	-0.014	-0.012	-0.009	-0.007	-0.005	-0.002	0	+0.002	+0.005	+0.007	+0.009	+0.012	+0.014	+0.014	+0.016	+0.018	+0.021	+0.023	28
29	-0.017	-0.015	-0.012	-0.010	-0.007	-0.005	-0.002	0	+0.002	+0.005	+0.007	+0.010	+0.012	+0.015	+0.015	+0.017	+0.020	+0.022	+0.025	29
30	-0.018	-0.016	-0.013	-0.010	-0.008	-0.005	-0.003	0	+0.003	+0.005	+0.008	+0.010	+0.013	+0.016	+0.016	+0.018	+0.021	+0.023	+0.026	30
31	-0.019	-0.017	-0.014	-0.011	-0.008	-0.006	-0.003	0	+0.003	+0.006	+0.008	+0.011	+0.014	+0.017	+0.017	+0.019	+0.022	+0.025	+0.028	31
32	-0.021	-0.018	-0.015	-0.012	-0.009	-0.006	-0.003	0	+0.003	+0.006	+0.009	+0.012	+0.015	+0.018	+0.018	+0.021	+0.023	+0.026	+0.029	32
33	-0.022	-0.019	-0.016	-0.012	-0.009	-0.006	-0.003	0	+0.003	+0.006	+0.009	+0.012	+0.016	+0.019	+0.019	+0.022	+0.025	+0.028	+0.031	33
34	-0.023	-0.020	-0.017	-0.013	-0.010	-0.006	-0.003	0	+0.003	+0.007	+0.010	+0.013	+0.017	+0.020	+0.020	+0.023	+0.026	+0.030	+0.033	34
35	-0.025	-0.021	-0.018	-0.014	-0.011	-0.007	-0.004	0	+0.004	+0.007	+0.010	+0.014	+0.018	+0.021	+0.021	+0.025	+0.028	+0.032	+0.035	35

Remarks: This table shows the values for $P=105.3 \text{ kPa}$ (790 mmHg) in $\alpha = \frac{0.621(S_s - 1)}{\frac{P}{P_s} - 1}$

where, S_s : specific gravity (of moist gas) obtained by effluence method
 P_s : steam pressure (kPa) (mmHg) at the measuring temperature
 P : total gas pressure in the measuring apparatus i.e. sum of the atmospheric pressure at the time of measurement and the pressure in the apparatus (kPa) (mmHg)

- (2) Open the cock of the pycnometer in the balance room to let the room air enter. Weigh the pycnometer with the cock opened. Take this mass as W_B .
- (3) Connect the pycnometer again as shown in Fig. 44. Repeat discharge and dry-air suction several times in the same operation as in (1) to displace the inside and fill the dry air at the atmospheric pressure into the pycnometer, and close the pycnometer cock. Remove the pycnometer and immerse the bulb portion of the pycnometer into the thermostatic water bath kept at a few degrees above room temperature. Keep this condition for several minutes. When the temperature of the pycnometer has stabilized, open the cock of the pycnometer for several seconds to make the pressure in the pycnometer equal to the atmospheric pressure and close the cock again. Take the pycnometer out of the thermostatic water bath and weigh it after removing water droplets. Take this mass as W_A .
- (4) Connect the pycnometer as shown in Fig. 44, and evacuate with a vacuum pump in the same way as in (1). Then, let the sample gas flow into it. Repeat this operation to fill the sample gas in the pycnometer. The sample gas pressure to be filled in the pycnometer shall be several tens Pa {several mmH₂O} higher than the atmospheric pressure. Close the cock of the pycnometer and remove the pycnometer. Immerse the bulb portion into a thermostatic water bath at the same temperature as in (3). Keep this condition for several minutes. When the temperature of the pycnometer has stabilized, open the cock for several seconds to make the pressure in the pycnometer equal to the atmospheric pressure and close the cock again. Take out the pycnometer from the thermostatic water bath, and weigh it after wiping water droplets. Take this mass as W_G .

To measure the specific gravity of the sample gas in the dry condition, connect a U-tube filled with desiccant such as calcium chloride specified in JIS K 8124, magnesium perchlorate specified in JIS K 8228, or the like in the flow path of the sample gas to preliminarily remove the moisture.

- (5) Furthermore, read out the indications of the barometer and thermometer attached to the barometer at the time of measurement.

8.3.4 Calculation The specific gravity shall be calculated according to the following formula:

- (1) Volume of the air displaced by the pycnometer

$$V_T = \frac{W_B}{\rho_s} + \frac{W_A - W_G}{0.0012}$$

- (2) Mass of the pycnometer

$$w_B = W_B \left[1 + 0.0012 \left(\frac{1}{\rho_s} - \frac{1}{\rho_w} \right) \right]$$

- (3) Mass of the pycnometer filled with the air

$$w_A = W_A \left[1 + 0.0012 \left(\frac{V_T}{W_A} - \frac{1}{\rho_w} \right) \right]$$

- (4) Mass of the pycnometer filled with the sample gas

$$w_G = W_G \left[1 + 0.0012 \left(\frac{V_T}{W_G} - \frac{1}{\rho_w} \right) \right]$$

- (5) Specific gravity of the sample gas

$$G = \frac{w_G - w_B}{w_A - w_B}$$

where, G : specific gravity of sample gas
 V_T : volume of air displaced by pycnometer (ml)
 W_V : apparent mass of pycnometer after making the inside vacuum (g)
 W_A : apparent mass of pycnometer filled with dry air (g)
 W_B : apparent mass of pycnometer (g)
 W_G : apparent mass of pycnometer filled with sample gas (g)
 ρ_s : density of material glass for pycnometer (g/ml)
 (2.3 for boro-silicate glass)
 ρ_w : density of weight of chemical balance 8.0 (g/cm³)
 w_A : mass of pycnometer filled with dry air (g)
 w_B : mass of pycnometer (g)
 w_G : mass of pycnometer filled with sample gas (g)
 0.0012: density of air at ordinary temperature (near 20°C) (g/ml)

8.3.5 Expression of measured result The measured results shall be expressed as follows:

- (1) Measurement shall be repeated twice by the same person in the same method. Confirm that the specific-gravity values of the two times' tests satisfy the tolerance 0.005, and when it is satisfied, obtain the average. If not satisfied, perform according to JIS Z 8402.
- (2) The measured specific gravity values shall be rounded off to two places of decimals according to JIS Z 8401 and the measuring method is indicated.

8.4 Method for obtaining by calculation

8.4.1 Summary The specific gravity of sample gas is obtained according to calculation by using the component composition obtained by 5. and the specific gravities of respective components.

8.4.2 Calculation The calculation of specific gravity shall be in accordance with the following formulae.

$$S = \frac{\sum C_{Mi} S_i}{Z}$$

$$Z = 1 - (\sum C_{Mi} \sqrt{b_i})^2 + 0.0005(2C_{MH} - C_{MH}^2)$$

$$b_i = 1 - Z_i$$

where, S : specific gravity of sample gas
 C_{Mi} : mol content rate of component i ⁽²⁴⁾
 S_i : specific gravity in the ideal condition of component i ⁽²⁵⁾
 Z : compression coefficient of sample gas
 Z_i : compression coefficient of component i ⁽²⁵⁾
 $\sqrt{b_i}$: compression adding coefficient of component i
 C_{MH} : mol content rate of hydrogen in sample gas ⁽²⁴⁾

Notes ⁽²⁴⁾ Obtain to four places of decimals.

⁽²⁵⁾ Obtain from Table 16.

Further, in the case of converting to mol content rate from volume percentage (vol %), use the following formula.

$$C_{Mi} = \frac{\frac{C_{Vi}}{Z_i}}{\sum \frac{C_{Vi}}{Z_i}}$$

where, C_{Vi} : volume percentage of component i (vol %)
 C_{Mi} : mol content rate of component i
 Z_i : compression coefficient of component i ⁽²⁵⁾

- Remarks 1. In the case of expression as series by adding, calculate by using the specific gravity, and compression coefficient of representative component out of components contained in it.
2. In the case where the high boiling-point hydrocarbon not less than C_6 is determined integrally as C_6^+ by using back flushing operation according to Remarks 3. of 5.2, when paraffins are main component calculate by representing with hexane, and when the aromatic hydrocarbons are main component calculate by representing with benzene.

3. In the case of natural gas, and where the fact that there is no difference practically interferent to calculation result is confirmed and further the agreement between the parties concerned with delivery is performed, the specific gravity may be calculated according to the following formula.

$$S = \sum \left(S_{vi} \frac{C_{vi}}{100} \right)$$

where, S : specific gravity of sample gas

C_{vi} : volume percentage of component i (vol %)

S_{vi} : specific gravity in the actually existing condition of component i

Specific gravities in actually existing condition of pure gas to be used for this calculation are shown in Attached Table 9.

Informative reference: In the case of obtaining Z and S , refer to Informative reference Attached Table 3.

8.4.3 Expression of measuring result As to measurement of specific gravity, round off to three places of decimals according to JIS Z 8401 to express and further append the measuring method.

Attached Table 1. Correction coefficient for atmospheric pressure conversion (α) (1)

Unit: kPa

t	B	87.8	89.1	90.4	91.8	93.1	94.4	95.8	97.1	98.4	99.8	101.1	102.4	103.7
1		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
3		0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
4		0.05	0.05	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
5		0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
6		0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.11
7		0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12
8		0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13
9		0.13	0.13	0.13	0.13	0.13	0.13	0.15	0.15	0.15	0.15	0.15	0.15	0.16
10		0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17
11		0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.19	0.19	0.19
12		0.17	0.17	0.17	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20
13		0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.23
14		0.20	0.20	0.21	0.21	0.21	0.21	0.21	0.23	0.23	0.23	0.23	0.24	0.24
15		0.21	0.21	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.25	0.25	0.25
16		0.23	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.27	0.27	0.27	0.27
17		0.24	0.25	0.25	0.25	0.25	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.29
18		0.25	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.29	0.29	0.29	0.31	0.31
19		0.27	0.28	0.28	0.28	0.29	0.29	0.29	0.31	0.31	0.31	0.32	0.32	0.32
20		0.29	0.29	0.29	0.29	0.31	0.31	0.31	0.32	0.32	0.32	0.33	0.33	0.33
21		0.31	0.31	0.31	0.32	0.32	0.32	0.33	0.33	0.33	0.35	0.35	0.35	0.36
22		0.32	0.32	0.32	0.33	0.33	0.33	0.35	0.35	0.35	0.36	0.36	0.37	0.37
23		0.33	0.33	0.33	0.35	0.35	0.36	0.36	0.36	0.37	0.37	0.37	0.39	0.39
24		0.35	0.35	0.36	0.36	0.36	0.37	0.37	0.37	0.39	0.39	0.40	0.40	0.41
25		0.36	0.36	0.37	0.37	0.37	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.43
26		0.37	0.37	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.43	0.43	0.44	0.44
27		0.39	0.39	0.40	0.40	0.41	0.41	0.43	0.43	0.43	0.44	0.44	0.45	0.45
28		0.40	0.41	0.41	0.41	0.43	0.43	0.44	0.44	0.45	0.45	0.47	0.47	0.48
29		0.41	0.43	0.43	0.44	0.44	0.44	0.45	0.45	0.47	0.47	0.48	0.48	0.49
30		0.43	0.44	0.44	0.45	0.45	0.47	0.47	0.48	0.48	0.49	0.49	0.51	0.51
31		0.44	0.45	0.45	0.47	0.47	0.48	0.48	0.49	0.49	0.51	0.51	0.52	0.52
32		0.45	0.47	0.47	0.48	0.48	0.49	0.49	0.51	0.51	0.52	0.53	0.53	0.55
33		0.47	0.48	0.48	0.49	0.51	0.51	0.52	0.52	0.53	0.53	0.55	0.55	0.56
34		0.48	0.49	0.51	0.51	0.52	0.52	0.53	0.53	0.55	0.55	0.56	0.57	0.57
35		0.51	0.51	0.52	0.52	0.53	0.53	0.55	0.56	0.56	0.57	0.57	0.59	0.59
36		0.52	0.52	0.53	0.53	0.55	0.56	0.56	0.57	0.57	0.59	0.59	0.60	0.61
37		0.53	0.53	0.55	0.55	0.56	0.57	0.57	0.59	0.59	0.60	0.61	0.61	0.63
38		0.55	0.55	0.56	0.57	0.57	0.59	0.59	0.60	0.61	0.61	0.63	0.64	0.64
39		0.56	0.56	0.57	0.59	0.59	0.60	0.61	0.61	0.63	0.63	0.64	0.65	0.65
40		0.57	0.57	0.59	0.60	0.60	0.61	0.63	0.63	0.64	0.65	0.65	0.67	0.68

Remarks: $B_0 = B - \alpha$

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Attached Table 2. Correction coefficient for atmospheric
pressure conversion (α)(2)

Unit: mmHg

t	B	660	670	680	690	700	710	720	730	740	750	760	770	780
1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
3		0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4		0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5		0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
6		0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8
7		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9
8		0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0
9		1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.2
10		1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3
11		1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4
12		1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5
13		1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.7
14		1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8
15		1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9
16		1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0
17		1.8	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.2
18		1.9	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.3	2.3
19		2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4
20		2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	2.5
21		2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	2.5	2.6	2.6	2.6	2.7
22		2.4	2.4	2.4	2.5	2.5	2.5	2.6	2.6	2.6	2.7	2.7	2.8	2.8
23		2.5	2.5	2.5	2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.9	2.9
24		2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.9	2.9	3.0	3.0	3.1
25		2.7	2.7	2.8	2.8	2.8	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.2
26		2.8	2.8	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.2	3.2	3.3	3.3
27		2.9	2.9	3.0	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.3	3.4	3.4
28		3.0	3.1	3.1	3.1	3.2	3.2	3.3	3.3	3.4	3.4	3.5	3.5	3.6
29		3.1	3.2	3.2	3.3	3.3	3.3	3.4	3.4	3.5	3.5	3.6	3.6	3.7
30		3.2	3.3	3.3	3.4	3.4	3.5	3.5	3.6	3.6	3.7	3.7	3.8	3.8
31		3.3	3.4	3.4	3.5	3.5	3.6	3.6	3.7	3.7	3.8	3.8	3.9	3.9
32		3.4	3.5	3.5	3.6	3.6	3.7	3.7	3.8	3.8	3.9	4.0	4.0	4.1
33		3.5	3.6	3.6	3.7	3.8	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.2
34		3.6	3.7	3.8	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.2	4.3	4.3
35		3.8	3.8	3.9	3.9	4.0	4.0	4.1	4.2	4.2	4.3	4.3	4.4	4.4
36		3.9	3.9	4.0	4.0	4.1	4.2	4.2	4.3	4.3	4.4	4.4	4.5	4.6
37		4.0	4.0	4.1	4.1	4.2	4.3	4.3	4.4	4.4	4.5	4.6	4.6	4.7
38		4.1	4.1	4.2	4.3	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.8	4.8
39		4.2	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8	4.9	4.9
40		4.3	4.3	4.4	4.5	4.5	4.6	4.7	4.7	4.8	4.9	4.9	5.0	5.1

Remarks: $B_0 = B - \alpha$

Attached Table 3. Saturated steam pressure of water (1)

Unit: kPa

Temperature (°C)	0	1	2	3	4	5	6	7	8	9
0	.610 66	.615 12	.619 60	.624 11	.628 65	.633 22	.637 82	.642 45	.647 11	.651 80
1	.656 52	.661 27	.666 05	.670 86	.675 70	.680 57	.685 47	.690 41	.695 37	.700 37
2	.705 40	.710 46	.715 55	.720 67	.725 83	.731 02	.736 24	.741 50	.746 79	.752 11
3	.757 47	.762 86	.768 28	.773 74	.779 23	.784 76	.790 32	.795 91	.801 54	.807 21
4	.812 91	.818 65	.824 42	.830 23	.836 07	.841 96	.847 87	.853 83	.859 82	.865 85
5	.871 91	.878 02	.884 16	.890 34	.896 55	.902 81	.909 10	.915 43	.921 81	.928 22
6	.934 67	.941 16	.947 69	.954 25	.960 86	.967 51	.974 20	.980 94	.987 71	.994 52
7	1.001 4	1.008 3	1.015 2	1.022 2	1.029 2	1.036 3	1.043 4	1.050 5	1.057 7	1.065 0
8	1.072 3	1.079 6	1.086 9	1.094 4	1.101 8	1.109 3	1.116 9	1.124 5	1.132 1	1.139 8
9	1.147 5	1.155 3	1.163 1	1.171 0	1.178 9	1.186 9	1.194 9	1.202 9	1.211 0	1.219 2
10	1.227 4	1.235 6	1.243 9	1.252 3	1.260 7	1.269 1	1.277 6	1.286 2	1.294 8	1.303 4
11	1.312 1	1.320 9	1.329 7	1.338 5	1.347 4	1.356 4	1.365 4	1.374 5	1.383 6	1.392 8
12	1.402 0	1.411 2	1.420 6	1.430 0	1.439 4	1.448 9	1.458 4	1.468 0	1.477 7	1.487 4
13	1.497 2	1.507 0	1.516 9	1.526 8	1.536 8	1.546 9	1.557 0	1.567 2	1.577 4	1.587 7
14	1.598 0	1.608 4	1.618 9	1.629 4	1.640 0	1.650 7	1.661 4	1.672 1	1.683 0	1.693 8
15	1.704 8	1.715 8	1.726 9	1.738 0	1.749 2	1.760 5	1.771 8	1.783 2	1.794 7	1.806 2
16	1.817 8	1.829 4	1.841 1	1.852 9	1.864 8	1.876 7	1.888 7	1.900 7	1.912 8	1.925 0
17	1.937 3	1.949 6	1.962 0	1.974 4	1.987 0	1.999 6	2.012 2	2.025 0	2.037 8	2.050 6
18	2.063 6	2.076 6	2.089 7	2.102 9	2.116 1	2.129 4	2.142 8	2.156 3	2.169 8	2.183 4
19	2.197 1	2.210 8	2.224 7	2.238 6	2.252 6	2.266 6	2.280 8	2.295 0	2.309 3	2.323 6
20	2.338 1	2.352 6	2.367 2	2.381 9	2.396 6	2.411 5	2.426 4	2.441 4	2.456 5	2.471 7
21	2.486 9	2.502 2	2.517 7	2.533 1	2.548 7	2.564 4	2.580 1	2.596 0	2.611 9	2.627 9
22	2.644 0	2.660 1	2.676 4	2.692 7	2.709 2	2.725 7	2.742 3	2.759 0	2.775 8	2.792 7
23	2.809 6	2.826 7	2.843 8	2.861 1	2.878 4	2.895 8	2.913 3	2.930 9	2.948 6	2.966 4
24	2.984 3	3.002 3	3.020 3	3.038 5	3.056 7	3.075 1	3.093 6	3.112 1	3.130 7	3.149 5
25	3.168 3	3.187 3	3.206 3	3.225 4	3.244 7	3.264 0	3.283 4	3.303 0	3.322 6	3.342 4
26	3.362 2	3.382 1	3.402 2	3.422 3	3.442 6	3.463 0	3.483 4	3.504 0	3.524 7	3.545 5
27	3.566 3	3.587 3	3.608 4	3.629 6	3.651 0	3.672 4	3.693 9	3.715 6	3.737 3	3.759 2
28	3.781 2	3.803 3	3.825 5	3.847 8	3.870 2	3.892 8	3.915 4	3.938 2	3.961 1	3.984 1
29	4.007 2	4.030 4	4.053 8	4.077 3	4.100 8	4.124 6	4.148 4	4.172 3	4.196 4	4.220 6
30	4.244 9	4.269 3	4.293 9	4.318 5	4.343 3	4.368 3	4.393 3	4.418 5	4.443 8	4.469 2
31	4.494 7	4.520 4	4.546 2	4.572 1	4.598 2	4.624 4	4.650 7	4.677 1	4.703 7	4.730 4
32	4.757 2	4.784 2	4.811 3	4.838 5	4.865 9	4.893 4	4.921 1	4.948 8	4.976 7	5.004 8
33	5.033 0	5.061 3	5.089 7	5.118 3	5.147 1	5.175 9	5.205 0	5.234 1	5.263 4	5.292 9
34	5.322 4	5.352 2	5.382 0	5.412 1	5.442 2	5.472 5	5.503 0	5.533 6	5.564 3	5.595 2
35	5.626 2	5.657 4	5.688 8	5.720 3	5.751 9	5.783 7	5.815 6	5.847 7	5.880 0	5.912 4
36	5.945 0	5.977 7	6.010 5	6.043 6	6.076 7	6.110 1	6.143 6	6.177 2	6.211 1	6.245 0
37	6.279 2	6.313 5	6.347 9	6.382 6	6.417 3	6.452 3	6.487 4	6.522 7	6.558 1	6.593 7
38	6.629 5	6.665 5	6.701 6	6.737 9	6.774 3	6.811 0	6.847 7	6.884 7	6.921 9	6.959 2
39	6.996 7	7.034 3	7.072 1	7.110 2	7.148 3	7.186 7	7.225 3	7.264 0	7.302 9	7.341 9
40	7.381 2	7.420 6	7.460 3	7.500 1	7.540 1	7.580 2	7.620 6	7.661 1	7.701 9	7.742 8
41	7.783 9	7.825 2	7.866 6	7.908 3	7.950 2	7.992 2	8.034 5	8.076 9	8.119 5	8.162 3
42	8.205 4	8.248 6	8.292 0	8.335 6	8.379 4	8.423 4	8.467 6	8.512 0	8.556 6	8.601 4
43	8.646 4	8.691 6	8.737 0	8.782 6	8.828 4	8.874 4	8.920 6	8.967 1	9.013 7	9.060 6
44	9.107 6	9.154 9	9.202 4	9.250 1	9.298 0	9.346 1	9.394 5	9.443 0	9.491 8	9.540 7
45	9.589 9	9.639 4	9.689 0	9.738 9	9.788 9	9.839 2	9.889 8	9.940 5	9.991 5	10.043
46	10.094	10.146	10.198	10.250	10.302	10.355	10.407	10.460	10.514	10.567
47	10.621	10.675	10.729	10.783	10.838	10.893	10.948	11.003	11.059	11.115
48	11.171	11.227	11.284	11.341	11.398	11.455	11.513	11.571	11.629	11.687
49	11.745	11.804	11.863	11.923	11.982	12.042	12.102	12.163	12.223	12.284
50	12.345	12.406	12.468	12.530	12.592	12.655	12.717	12.780	12.844	12.907

Remarks: Cited from JIS Z 8806.

When the value in this table is used to calculations specified in this Standard, it shall be rounded off to two places of decimals.

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Attached Table 4. Saturated steam pressure of water (2)

Unit: mmHg

Temperature (°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	4.581	4.615	4.648	4.682	4.716	4.750	4.785	4.820	4.855	4.890
1	4.925	4.961	4.997	5.033	5.069	5.105	5.142	5.179	5.216	5.254
2	5.292	5.329	5.368	5.406	5.445	5.484	5.523	5.562	5.602	5.642
3	5.681	5.722	5.763	5.804	5.845	5.886	5.928	5.970	6.012	6.055
4	6.098	6.141	6.184	6.227	6.271	6.315	6.360	6.404	6.449	6.494
5	6.540	6.586	6.632	6.678	6.725	6.772	6.819	6.866	6.914	6.962
6	7.010	7.059	7.108	7.157	7.207	7.257	7.307	7.357	7.408	7.459
7	7.510	7.562	7.614	7.666	7.719	7.772	7.825	7.879	7.933	7.987
8	8.042	8.097	8.152	8.208	8.263	8.320	8.377	8.433	8.491	8.548
9	8.606	8.665	8.723	8.782	8.841	8.901	8.961	9.021	9.082	9.143
10	9.205	9.267	9.329	9.392	9.455	9.518	9.582	9.646	9.710	9.775
11	9.840	9.906	9.972	10.04	10.10	10.17	10.24	10.31	10.38	10.45
12	10.51	10.58	10.65	10.72	10.79	10.87	10.94	11.01	11.08	11.15
13	11.23	11.30	11.38	11.45	11.52	11.60	11.68	11.75	11.83	11.91
14	11.98	12.06	12.14	12.22	12.30	12.38	12.46	12.54	12.62	12.70
15	12.78	12.87	12.95	13.03	13.12	13.20	13.29	13.37	13.46	13.54
16	13.63	13.72	13.81	13.89	13.98	14.07	14.16	14.25	14.34	14.43
17	14.53	14.62	14.71	14.81	14.90	14.99	15.09	15.18	15.28	15.38
18	15.47	15.57	15.67	15.77	15.87	15.97	16.07	16.17	16.27	16.37
19	16.47	16.58	16.68	16.79	16.89	17.00	17.10	17.21	17.32	17.42
20	17.53	17.64	17.75	17.86	17.97	18.08	18.19	18.31	18.42	18.53
21	18.65	18.76	18.88	18.99	19.11	19.23	19.35	19.46	19.58	19.70
22	19.82	19.95	20.07	20.19	20.31	20.44	20.56	20.69	20.81	20.94
23	21.07	21.19	21.32	21.45	21.58	21.71	21.84	21.98	22.11	22.24
24	22.38	22.51	22.65	22.78	22.92	23.06	23.19	23.33	23.47	23.61
25	23.76	23.90	24.04	24.18	24.33	24.47	24.62	24.76	24.91	25.06
26	25.21	25.36	25.51	25.66	25.81	25.96	26.12	26.27	26.43	26.58
27	26.74	26.90	27.05	27.21	27.37	27.53	27.70	27.86	28.02	28.18
28	28.35	28.52	28.68	28.85	29.02	29.19	29.36	29.53	29.70	29.87
29	30.04	30.22	30.39	30.57	30.75	30.92	31.10	31.28	31.46	31.64
30	31.83	32.01	32.19	32.38	32.56	32.75	32.94	33.13	33.32	33.51
31	33.70	33.89	34.08	34.28	34.47	34.67	34.87	35.07	35.27	35.47
32	35.67	35.87	36.07	36.28	36.48	36.69	36.89	37.10	37.31	37.52
33	37.73	37.95	38.16	38.37	38.59	38.81	39.02	39.24	39.46	39.68
34	39.90	40.13	40.35	40.58	40.80	41.03	41.26	41.49	41.72	41.95
35	42.18	42.41	42.65	42.89	43.12	43.36	43.60	43.84	44.08	44.33
36	44.57	44.82	45.06	45.31	45.56	45.81	46.06	46.31	46.56	46.82
37	47.08	47.33	47.59	47.85	48.11	48.37	48.64	48.90	49.17	49.43
38	49.70	49.97	50.24	50.51	50.79	51.06	51.34	51.62	51.89	52.17
39	52.45	52.74	53.02	53.31	53.59	53.88	54.17	54.46	54.75	55.04
40	55.34	55.63	55.93	56.23	56.53	56.83	57.13	57.44	57.74	58.05
41	58.36	58.67	58.98	59.29	59.60	59.92	60.24	60.55	60.87	61.19
42	61.52	61.84	62.17	62.49	62.82	63.15	63.48	63.81	64.15	64.49
43	64.82	65.16	65.50	65.84	66.19	66.53	66.88	67.23	67.58	67.93
44	68.28	68.64	68.99	69.35	69.71	70.07	70.43	70.80	71.16	71.53
45	71.90	72.27	72.64	73.01	73.39	73.77	74.15	74.53	74.91	75.29
46	75.67	76.06	76.45	76.84	77.23	77.63	78.03	78.43	78.82	79.22
47	79.63	80.03	80.44	80.84	81.25	81.67	82.08	82.49	82.91	83.33
48	83.75	84.17	84.60	85.03	85.45	85.88	86.31	86.74	87.18	87.62
49	88.06	88.50	88.94	89.39	89.84	90.29	90.74	91.19	91.64	92.10
50	92.56	93.02	93.48	93.95	94.41	94.88	95.35	95.82	96.29	96.77

Remarks: When the value in this table is used to calculations specified in this standard, it shall be rounded off to one place of decimal.

Attached Table 5. Values of $\left(\frac{273.15}{t_g + 273.15} \times \frac{1}{P_0}\right)$ (where $P_0 = 101.32 \text{ kPa}$ {760 mmHg})
(1)Unit: kPa^{-1}

Temperature (°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.009 871	9 863	9 863	9 856	9 856	9 848	9 848	9 841	9 841	9 833
1	0.009 833	9 833	9 826	9 826	9 818	9 818	9 811	9 811	9 803	9 803
2	0.009 796	9 796	9 788	9 788	9 781	9 781	9 773	9 773	9 766	9 766
3	0.009 766	9 758	9 758	9 751	9 751	9 743	9 743	9 736	9 736	9 728
4	0.009 728	9 721	9 721	9 713	9 713	9 706	9 706	9 706	9 698	9 698
5	0.009 691	9 691	9 683	9 683	9 676	9 676	9 668	9 668	9 661	9 661
6	0.009 661	9 653	9 653	9 646	9 646	9 638	9 638	9 631	9 631	9 623
7	0.009 623	9 616	9 616	9 616	9 608	9 608	9 601	9 601	9 593	9 593
8	0.009 586	9 586	9 578	9 578	9 578	9 571	9 571	9 563	9 563	9 556
9	0.009 556	9 548	9 548	9 541	9 541	9 541	9 533	9 533	9 526	9 526
10	0.009 518	9 518	9 511	9 511	9 511	9 503	9 503	9 496	9 496	9 488
11	0.009 488	9 481	9 481	9 481	9 473	9 473	9 466	9 466	9 458	9 458
12	0.009 451	9 451	9 451	9 443	9 443	9 436	9 436	9 428	9 428	9 421
13	0.009 421	9 421	9 413	9 413	9 406	9 406	9 398	9 398	9 398	9 391
14	0.009 391	9 383	9 383	9 376	9 376	9 368	9 368	9 368	9 361	9 361
15	0.009 353	9 353	9 346	9 346	9 346	9 338	9 338	9 331	9 331	9 323
16	0.009 323	9 323	9 316	9 316	9 308	9 308	9 301	9 301	9 301	9 293
17	0.009 293	9 286	9 286	9 278	9 278	9 278	9 271	9 271	9 263	9 263
18	0.009 256	9 256	9 256	9 248	9 248	9 241	9 241	9 233	9 233	9 233
19	0.009 226	9 226	9 218	9 218	9 218	9 211	9 211	9 203	9 203	9 196
20	0.009 196	9 196	9 188	9 188	9 181	9 181	9 181	9 173	9 173	9 166
21	0.009 166	9 158	9 158	9 158	9 151	9 151	9 143	9 143	9 143	9 136
22	0.009 136	9 128	9 128	9 121	9 121	9 121	9 113	9 113	9 106	9 106
23	0.009 106	9 098	9 098	9 091	9 091	9 091	9 083	9 083	9 076	9 076
24	0.009 076	9 068	9 068	9 061	9 061	9 053	9 053	9 053	9 046	9 046
25	0.009 038	9 038	9 038	9 031	9 031	9 023	9 023	9 023	9 016	9 016
26	0.009 008	9 008	9 008	9 001	9 001	8 993	8 993	8 993	8 986	8 986
27	0.008 978	8 978	8 978	8 971	8 971	8 963	8 963	8 963	8 956	8 956
28	0.008 948	8 948	8 948	8 941	8 941	8 933	8 933	8 933	8 926	8 926
29	0.008 926	8 918	8 918	8 911	8 911	8 911	8 903	8 903	8 896	8 896
30	0.008 896	8 888	8 888	8 881	8 881	8 881	8 873	8 873	8 866	8 866
31	0.008 866	8 858	8 858	8 858	8 851	8 851	8 843	8 843	8 843	8 836
32	0.008 836	8 828	8 828	8 828	8 821	8 821	8 821	8 813	8 813	8 806
33	0.008 806	8 806	8 798	8 798	8 791	8 791	8 791	8 783	8 783	8 783
34	0.008 776	8 776	8 768	8 768	8 768	8 761	8 761	8 753	8 753	8 753
35	0.008 746	8 746	8 746	8 738	8 738	8 731	8 731	8 731	8 723	8 723
36	0.008 723	8 716	8 716	8 708	8 708	8 708	8 701	8 701	8 701	8 693
37	0.008 693	8 686	8 686	8 686	8 678	8 678	8 678	8 671	8 671	8 663
38	0.008 663	8 663	8 656	8 656	8 656	8 648	8 648	8 648	8 641	8 641
39	0.008 633	8 633	8 633	8 626	8 626	8 626	8 618	8 618	8 611	8 611
40	0.008 611	8 603	8 603	8 603	8 596	8 596	8 596	8 588	8 588	8 581

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Attached Table 6. Values of $\left(\frac{273.15}{t_g + 273.15} \times \frac{1}{P_0}\right)$ (where $P_0 = 760 \text{ mmHg} \{101.32 \text{ kPa}\}$)
(2)

Unit: mmHg⁻¹

Temperature (°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.001 316	1 315	1 315	1 314	1 314	1 313	1 313	1 312	1 312	1 311
1	0.001 311	1 311	1 310	1 310	1 309	1 309	1 308	1 308	1 307	1 307
2	0.001 306	1 306	1 305	1 305	1 304	1 304	1 303	1 303	1 302	1 302
3	0.001 302	1 301	1 301	1 300	1 300	1 299	1 299	1 298	1 298	1 297
4	0.001 297	1 296	1 296	1 295	1 295	1 294	1 294	1 294	1 293	1 293
5	0.001 292	1 292	1 291	1 291	1 290	1 290	1 289	1 289	1 288	1 288
6	0.001 288	1 287	1 287	1 286	1 286	1 285	1 285	1 284	1 284	1 283
7	0.001 283	1 282	1 282	1 282	1 281	1 281	1 280	1 280	1 279	1 279
8	0.001 278	1 278	1 277	1 277	1 277	1 276	1 276	1 275	1 275	1 274
9	0.001 274	1 273	1 273	1 272	1 272	1 272	1 271	1 271	1 270	1 270
10	0.001 269	1 269	1 268	1 268	1 268	1 267	1 267	1 266	1 266	1 265
11	0.001 265	1 264	1 264	1 264	1 263	1 263	1 262	1 262	1 261	1 261
12	0.001 260	1 260	1 260	1 259	1 259	1 258	1 258	1 257	1 257	1 256
13	0.001 256	1 256	1 255	1 255	1 254	1 254	1 253	1 253	1 253	1 252
14	0.001 252	1 251	1 251	1 250	1 250	1 249	1 249	1 249	1 248	1 248
15	0.001 247	1 247	1 246	1 246	1 246	1 245	1 245	1 244	1 244	1 243
16	0.001 243	1 243	1 242	1 242	1 241	1 241	1 240	1 240	1 240	1 239
17	0.001 239	1 238	1 238	1 237	1 237	1 237	1 236	1 236	1 235	1 235
18	0.001 234	1 234	1 234	1 233	1 233	1 232	1 232	1 231	1 231	1 231
19	0.001 230	1 230	1 229	1 229	1 229	1 228	1 228	1 227	1 227	1 226
20	0.001 226	1 226	1 225	1 225	1 224	1 224	1 224	1 223	1 223	1 222
21	0.001 222	1 221	1 221	1 221	1 220	1 220	1 219	1 219	1 219	1 218
22	0.001 218	1 217	1 217	1 216	1 216	1 216	1 215	1 215	1 214	1 214
23	0.001 214	1 213	1 213	1 212	1 212	1 212	1 211	1 211	1 210	1 210
24	0.001 210	1 209	1 209	1 208	1 208	1 207	1 207	1 207	1 206	1 206
25	0.001 205	1 205	1 205	1 204	1 204	1 203	1 203	1 203	1 202	1 202
26	0.001 201	1 201	1 201	1 200	1 200	1 199	1 199	1 199	1 198	1 198
27	0.001 197	1 197	1 197	1 196	1 196	1 195	1 195	1 195	1 194	1 194
28	0.001 193	1 193	1 193	1 192	1 192	1 191	1 191	1 191	1 190	1 190
29	0.001 190	1 189	1 189	1 188	1 188	1 188	1 187	1 187	1 186	1 186
30	0.001 186	1 185	1 185	1 184	1 184	1 184	1 183	1 183	1 182	1 182
31	0.001 182	1 181	1 181	1 181	1 180	1 180	1 179	1 179	1 179	1 178
32	0.001 178	1 177	1 177	1 177	1 176	1 176	1 176	1 175	1 175	1 174
33	0.001 174	1 174	1 173	1 173	1 172	1 172	1 172	1 171	1 171	1 171
34	0.001 170	1 170	1 169	1 169	1 169	1 168	1 168	1 167	1 167	1 167
35	0.001 166	1 166	1 166	1 165	1 165	1 164	1 164	1 164	1 163	1 163
36	0.001 163	1 162	1 162	1 161	1 161	1 161	1 160	1 160	1 160	1 159
37	0.001 159	1 158	1 158	1 158	1 157	1 157	1 157	1 156	1 156	1 155
38	0.001 155	1 155	1 154	1 154	1 154	1 153	1 153	1 153	1 152	1 152
39	0.001 151	1 151	1 151	1 150	1 150	1 150	1 149	1 149	1 148	1 148
40	0.001 148	1 147	1 147	1 147	1 146	1 146	1 146	1 145	1 145	1 144

Attached Table 7. Humidity table for vent dry-wet ball hygrometer (When freezing
does not occur) (for atmospheric pressure of 101.32 kPa {760 mmHg} *)

Unit: %

Water-bulb temper- ature °C	Difference between-dry-bulb and wet-bulb temperature (°C)																																			
	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	
0	100	96	93	89	86	83	80	76	73	70	67	65	62	59	57	54	48	42	37	31	27	22	18	14	10											
1	100	97	93	90	87	83	80	77	75	72	69	66	64	61	59	56	50	44	39	34	30	25	21	17	14	10										
2	100	97	93	91	87	84	81	78	76	73	70	68	65	63	60	58	52	47	42	37	33	28	24	21	17	14	11									
3	100	97	94	91	88	85	82	79	77	74	72	69	67	64	62	60	54	49	44	39	35	31	27	23	20	17	14	11								
4	100	97	94	91	88	86	83	80	78	75	73	70	68	66	63	61	56	51	46	42	37	33	30	26	23	20	17	14	11							
5	100	97	94	91	89	86	84	81	79	76	74	71	69	67	65	63	57	53	48	44	40	36	32	29	25	22	19	17	14	12	10					
6	100	97	94	92	89	87	84	82	79	77	75	72	70	68	66	64	58	55	50	46	42	38	34	31	28	25	22	19	17	15	12	10				
7	100	97	95	92	90	87	85	82	80	78	76	73	71	69	67	65	60	56	52	48	44	40	37	33	30	27	24	22	19	17	15	13	11			
8	100	97	95	92	90	88	85	83	81	79	76	74	72	70	68	66	62	57	53	49	46	42	39	35	32	29	27	24	22	19	17	15	13	11	10	
9	100	98	95	93	90	88	86	84	81	79	77	75	73	71	69	68	63	59	56	51	47	44	40	37	34	32	29	26	24	22	20	18	16	14	12	
10	100	98	95	93	91	88	86	84	82	80	78	76	74	72	70	69	64	60	56	52	49	45	42	39	36	33	31	28	26	24	22	20	18	16	14	
11	100	98	95	93	91	89	87	85	83	81	79	77	75	73	71	69	65	61	57	54	50	47	44	41	38	35	33	30	28	26	24	22	20	18	16	
12	100	98	96	93	91	89	87	85	83	81	79	77	76	74	72	70	66	62	59	55	52	48	45	42	40	37	35	32	30	28	26	24	22	20	18	
13	100	98	96	94	92	90	88	86	84	82	80	78	76	75	73	71	67	63	60	56	53	50	47	44	41	39	36	34	32	29	27	25	24	22	20	
14	100	98	96	94	92	90	88	86	84	82	81	79	77	75	74	72	68	64	61	57	54	51	48	45	43	40	38	35	33	31	29	27	25	24	22	
15	100	98	96	94	92	90	88	86	85	83	81	79	78	76	74	73	69	65	62	59	55	52	50	47	44	42	39	37	35	33	31	29	27	25	24	
16	100	98	96	94	92	90	89	87	85	83	82	80	78	77	75	74	70	66	63	60	57	54	51	48	45	43	41	38	36	34	32	30	29	27	25	
17	100	98	96	94	92	91	89	87	85	84	82	80	79	77	76	74	71	67	64	61	58	55	52	49	47	44	42	40	38	36	34	32	30	28	27	
18	100	98	96	94	93	91	89	87	86	84	83	81	79	78	76	75	71	68	65	62	59	56	53	50	48	45	43	41	39	37	35	33	31	30	29	
19	100	98	96	95	93	91	89	88	86	85	83	81	80	78	77	76	72	69	65	62	59	57	54	51	49	47	44	42	40	38	36	34	33	31	29	
20	100	98	96	95	93	91	90	88	86	85	83	82	80	79	77	76	73	69	66	63	60	58	55	52	50	48	45	43	41	39	37	35	33	32	31	
21	100	98	97	95	93	92	90	88	87	85	84	82	81	79	78	77	73	70	67	64	61	58	56	53	51	49	46	44	42	40	39	37	35	33	32	
22	100	98	97	95	93	92	90	89	87	86	84	83	81	80	78	77	74	71	68	65	62	59	57	54	52	50	47	45	43	41	40	38	36	35	33	
23	100	98	97	95	93	92	90	89	87	86	84	83	82	80	79	78	74	71	68	65	63	60	58	55	53	51	48	46	44	42	41	39	37	36	34	
24	100	98	97	95	94	92	91	89	88	86	85	83	82	81	79	78	75	72	69	66	63	61	58	56	54	51	49	47	45	43	42	40	38	37	35	
25	100	98	97	95	94	92	91	89	88	86	85	84	82	81	80	78	75	72	69	67	64	62	59	57	54	52	50	48	46	44	43	41	39	38	36	
26	100	98	97	95	94	92	91	90	88	87	85	84	83	81	80	79	76	73	70	67	65	62	60	57	55	53	51	49	47	45	44	42	40	39	37	
27	100	98	97	95	94	92	91	90	88	87	86	84	83	82	81	79	76	73	71	68	65	63	60	58	56	54	52	50	48	46	44	43	41	39	38	
28	100	99	97	96	94	93	91	90	89	87	86	85	83	82	81	80	77	74	71	68	66	63	61	59	57	55	53	51	49	47	45	43	42	40	39	
29	100	99	97	96	94	93	91	90	89	87	86	85	84	82	81	80	77	74	72	69	66	64	62	60	57	55	53	51	49	48	46	44	43	41	40	
30	100	99	97	96	94	93	92	90	89	88	86	85	84	83	82	80	77	75	72	69	67	65	62	60	58	56	54	52	50	48	47	45	43	42	40	
31	100	99	97	96	94	93	92	90	89	88	87	85	84	83	82	81	78	75	73	70	68	65	63	61	59	57	55	53	51	49	47	46	44	43	41	
32	100	99	97	96	95	93	92	91	89	88	87	86	84	83	82	81	78	76	73	70	68	66	63	61	59	57	55	53	52	50	48	46	45	43	42	
33	100	99	97	96	95	93	92	91	90	88	87	86	85	84	82	81	79	76	73	71	68	66	64	62	60	58	56	54	52	50	49	47	46	44	43	
34	100	99	97	96	95	93	92	91	90	88	87	86	85	84	83	82	79	76	74	71	69	67	64	62	60	58	56	55	53	51	49	48	46			
35	100	99	97	96	95	94	92	91	90	89	87	86	85	84	83	82	79	77	74	72	69	67	65	63	61	59	57	55	53	52	50					
36	100	99	97	96	95	94	92	91	90	89	88	87	85	84	83	82	79	77	74	72	70	68	65	63	61	59	58	56	54							
37	100	99	97	96	95	94	92	91	90	89	88	87	86	84	83	82	80	77	75	72	70	68	66	64	62	60										
38	100	99	97	96	95	94	93	91	90	89	88	87	86	85	84	83	80	78	75	73	71	68	66	64	62											
39	100	99	97	96	95	94	93	92	90	89	88	87	86	85	84	83	80	78	75	73	71	69														
40	100	99	98	96	95	94	93	92	91	89	88	87	86	85	84	83	81	78	76	73	71															

Remarks *: Cited from JIS Z 8806.

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Attached Table 8. Thermometer exposed part indication correction value

$$t_i = t_1 + \theta$$

$$\theta = \frac{n(t_1 - t_r)}{6\,000}$$

where θ : corrected value

t_i : corrected temperature (°C)

t_1 : read out temperature (°C)

t_r : room temperature (°C)

n : exposed part degree (°C)

Exposed part degree n	Water temperature (t_1) - Room temperature (t_r)(°C)													
	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
1	0.000	000	000	000	001	001	001	001	001	001	002	002	002	002
2	0.000	001	001	001	001	001	002	002	002	003	003	003	004	004
3	0.001	001	001	001	002	002	003	003	004	004	005	005	006	006
4	0.001	001	001	002	002	003	003	004	005	005	006	007	007	008
5	0.001	001	002	002	003	003	004	005	006	007	008	008	009	010
6	0.001	002	002	003	003	004	005	006	007	008	009	010	011	012
7	0.001	002	002	003	004	005	006	007	008	009	011	012	013	014
8	0.001	002	003	003	004	005	007	008	009	011	012	013	015	016
9	0.002	002	003	004	005	006	008	009	011	012	014	015	017	018
10	0.002	003	003	004	005	007	008	010	012	013	015	017	018	020
11	0.002	003	004	005	006	007	009	011	013	015	017	018	020	022
12	0.002	003	004	005	006	008	010	012	014	016	018	020	022	024
13	0.002	003	004	005	007	009	011	013	015	017	020	022	024	026
14	0.002	004	005	006	007	009	012	014	016	019	021	023	026	028
15	0.003	004	005	006	008	010	013	015	018	020	023	025	028	030
16	0.003	004	005	007	008	011	013	016	019	021	024	027	029	032
17	0.003	004	006	007	009	011	014	017	020	023	026	028	031	034
18	0.003	005	006	008	009	012	015	018	021	024	027	030	033	036
19	0.003	005	006	008	010	013	016	019	022	025	029	032	035	038
20	0.003	005	007	008	010	013	017	020	023	027	030	033	037	040
21	0.004	005	007	009	011	014	018	021	025	028	032	035	039	042
22	0.004	006	007	009	011	015	018	022	026	029	033	037	040	044
23	0.004	006	008	010	012	015	019	023	027	031	035	038	042	046
24	0.004	006	008	010	012	016	020	024	028	032	036	040	044	048
25	0.004	006	008	010	013	017	021	025	029	033	038	042	046	050
26	0.004	007	009	011	013	017	022	026	030	035	039	043	048	052
27	0.005	007	009	011	014	018	023	027	032	036	041	045	050	054
28	0.005	007	009	012	014	019	023	028	033	037	042	047	051	056
29	0.005	007	010	012	015	019	024	029	034	039	043	048	053	058
30	0.005	008	010	013	015	020	025	030	035	040	045	050	055	060
31	0.005	008	010	013	016	021	026	031	036	041	047	052	057	062
32	0.005	008	011	013	016	021	027	032	037	043	048	053	059	064
33	0.006	008	011	014	017	022	028	033	039	044	050	055	061	066
34	0.006	009	011	014	017	023	028	034	040	045	051	057	062	068
35	0.006	009	012	015	018	023	029	035	041	047	053	058	064	070
36	0.006	009	012	015	018	024	030	036	042	048	054	060	066	072
37	0.006	009	012	015	019	025	031	037	043	049	056	062	068	074
38	0.006	010	013	016	019	025	032	038	044	051	057	063	070	076
39	0.007	010	013	016	020	026	033	039	046	052	059	065	072	078
40	0.007	010	013	017	020	027	033	040	047	053	060	067	073	080
41	0.007	010	014	017	021	027	034	041	048	055	062	068	075	082
42	0.007	011	014	018	021	028	035	042	049	056	063	070	077	084
43	0.007	011	014	018	022	029	036	043	050	057	065	072	079	086
44	0.007	011	015	018	022	029	037	044	051	059	066	073	081	088
45	0.008	011	015	019	023	030	038	045	053	060	068	075	083	090
46	0.008	012	015	019	023	031	038	046	054	061	069	077	084	092
47	0.008	012	016	020	024	031	039	047	055	063	071	078	086	094
48	0.008	012	016	020	024	032	040	048	056	064	072	080	088	096
49	0.008	012	016	020	025	033	041	049	057	065	074	082	090	098
50	0.008	013	017	021	025	033	042	050	058	067	075	083	092	100

Remarks: Exposed part degree is the length of the mercury column exposed to room temperature expressed in degree graduations.

Attached Table 9. Calorific value and specific gravity in actually existing condition of pure gas

No.	Component	Molecular formula	Total calorific value (kJ/m ³){kcal/m ³ }	True calorific value (kJ/m ³){kcal/m ³ }	Specific gravity (Air = 1)
1	Hydrogen	H ₂	12 780 { 3 053 }	10 830 { 2 587 }	0.069 5
2	Oxygen	O ₂	—	—	1.105
3	Nitrogen	N ₂	—	—	0.967
4	Carbon monoxide	CO	12 610 { 3 013 }	12 610 { 3 013 }	0.967
5	Carbon dioxide	CO ₂	—	—	1.529
6	Methane	CH ₄	39 940 { 9 540 }	36 020 { 8 605 }	0.555
7	Ethane	C ₂ H ₆	70 470 {16 830 }	64 550 {15 420 }	1.048
8	Ethylene	C ₂ H ₄	63 560 {15 180 }	59 620 {14 240 }	0.976
9	Propane	C ₃ H ₈	101 400 {24 220 }	93 390 {22 310 }	1.555
10	Propylene	C ₃ H ₆	93 730 {22 390 }	87 760 {20 960 }	1.480
11	Butane	C ₄ H ₁₀	134 300 {32 080 }	124 100 {29 650 }	2.094
12	Isobutane	C ₄ H ₁₀	133 100 {31 790 }	122 900 {29 370 }	2.081
13	1-Butene	C ₄ H ₈	126 300 {30 160 }	118 100 {28 220 }	2.013
14	Cis-2-butene	C ₄ H ₈	126 600 {30 250 }	118 400 {28 300 }	2.024
15	Trans-2-butene	C ₄ H ₈	126 300 {30 160 }	118 100 {28 220 }	2.021
16	Isobutene	C ₄ H ₈	125 500 {29 980 }	117 400 {28 040 }	2.014
17	1,3-Butadiene	C ₄ H ₆	117 600 {28 100 }	111 600 {26 650 }	1.934
18	Pentane	C ₅ H ₁₂	171 400 {40 950 }	158 700 {37 910 }	2.700
19	Isopentane	C ₅ H ₁₂	169 300 {40 450 }	156 800 {37 450 }	2.673
20	Neopentane	C ₅ H ₁₂	166 000 {39 660 }	153 600 {36 700 }	2.631
21	1-Pentene	C ₅ H ₁₀	161 900 {38 670 }	151 400 {36 170 }	2.597
22	Cis-2-pentene	C ₅ H ₁₀	162 000 {38 700 }	151 500 {36 190 }	2.603
23	Trans-2-pentene	C ₅ H ₁₀	161 800 {38 640 }	151 300 {36 130 }	2.603
24	2-Methyl-1-butene	C ₅ H ₁₀	160 600 {38 360 }	150 100 {35 860 }	2.587
25	3-Methyl-1-butene	C ₅ H ₁₀	160 000 {38 210 }	149 600 {35 740 }	2.572
26	2-Methyl-2-butene	C ₅ H ₁₀	160 500 {38 350 }	150 100 {35 850 }	2.590
27	Cyclopentane	C ₅ H ₁₀	159 200 {38 030 }	148 700 {35 520 }	2.596
28	Hexane	C ₆ H ₁₄	215 700 {51 520 }	199 900 {47 760 }	3.421
29	Isohexane	C ₆ H ₁₄	213 600 {51 020 }	198 000 {47 290 }	3.394
30	3-Methyl pentane	C ₆ H ₁₄	209 200 {49 970 }	193 900 {46 320 }	3.321
31	2,2-Dimethyl butane	C ₆ H ₁₄	211 100 {50 430 }	195 600 {46 730 }	3.362
32	2,3-Dimethyl butane	C ₆ H ₁₄	213 300 {50 950 }	197 700 {47 230 }	3.391
33	Benzene	C ₆ H ₆	163 300 {39 010 }	156 800 {37 460 }	2.985
34	Toluene	C ₇ H ₈	227 700 {54 400 }	217 600 {51 990 }	4.108

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Attached Table 10. Applicable Standards

JIS B 7410-Liquid-in-Glass Thermometers for Testing of Petroleum Products

JIS B 7505-Bourdon Tube Pressure Gauges

JIS K 0050-General Rules for Chemical Analysis

JIS K 0088-Methods for Determination of Benzene in Exhaust Gas

JIS K 0114-General Rules for Gas Chromatographic Analysis

JIS K 0115-General Rules for Molecular Absorptiometric Analysis

JIS K 0512-Hydrogen

JIS K 1101-Oxygen

JIS K 1107-High Purity Nitrogen

JIS K 1420-Sodium Thiosulfate (Crystalline)

JIS K 2240-Liquefied Petroleum Gases

JIS K 2839-Glasswares for Testing Apparatus of Petroleum Products

JIS K 8005-Standard Substances for Volumetric Analysis

JIS K 8034-Acetone

JIS K 8051-Isoamyl Alcohol, 3-Methylbutyl Alcohol

JIS K 8102-Ethanol (95)[Ethyl Alcohol(95)]

JIS K 8121-Potassium Chloride

JIS K 8124-Calcium Chloride (for Drying)

JIS K 8137-Iron (II) Chloride n Hydrate

JIS K 8150-Sodium Chloride

JIS K 8155-Barium Chloride Dihydrate

JIS K 8180-Hydrochloric Acid

JIS K 8193-N, N-Dimethyl-*p*-Phenylenediammonium Dihloride (Dimethyl-*p*-Phenylenediamine Hydrochloride)

JIS K 8228-Magnesium Perchlorate

JIS K 8374-Lead Acetate Trihydrate

JIS K 8500-N,N-Dimethylformamide

JIS K 8550-Silver Nitrate
JIS K 8568-Manganese Nitrate
JIS K 8576-Sodium Hydroxide
JIS K 8625-Sodium Carbonate, Anhydrous
JIS K 8659-Soluble Starch
JIS K 8680-Toluene
JIS K 8690-Naphthalene
JIS K 8722-Sodium Pentacyanonitrosulferrate (III) Dihydrate
JIS K 8798-Phenol
JIS K 8840-Bromocresol Green
JIS K 8844-Bromophenol Blue
JIS K 8858-Benzene
JIS K 8896-Methyl Red
JIS K 8897-Methylene Blue (Dihydrate, Trihydrate, Tetrahydrate)
JIS K 8913-Potassium Iodide
JIS K 8920-Iodine
JIS K 8922-Potassium Iodate
JIS K 8949-Sodium Sulfide Enneahydrate
JIS K 8951-Sulfuric Acid
JIS K 8953-Zinc Sulfate Heptahydrate
JIS K 8960-Ammonium Sulfate
JIS K 8962-Potassium Sulfate
JIS K 9551-Barium Perchlorate
JIS P 3801-Filter Paper (for Chemical Analysis)
JIS R 3503-Glass Apparatus for Chemical Analysis
JIS R 3505-Volumetric Glassware
JIS Z 8401-Rules for Rounding off of Numerical Values
JIS Z 8402-General Rules for Permissible Tolerance of Chemical Analyses
and Physical Tests

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JIS Z 8710-General Rules for Temperature Measurement

JIS Z 8806-Methods of Humidity Measurement

Attached Table 11. Corresponding International Standards

- ISO 6326-1: 1989 Natural gas - Determination of sulfur compounds -
Part 1: General introduction
- ISO 6327: 1981 Gas analysis - Determination of the water dew point of
natural gas - Cooled surface condensation hygrometers
- ISO 6568: 1981 Natural gas - Simple analysis by gas chromatography
- ISO 6569: 1981 Natural gas - Rapid analysis by gas chromatography
- ISO 6712: 1982 Gas analysis - Sampling and transfer equipment for
gases supplying an analytical unit
- ISO 6974: 1984 Natural gas - Determination of hydrogen, inert gases
and hydrocarbons up to C₈ - Gas chromatographic method
- ISO 6975: 1986 Natural gas - Determination of hydrocarbons from butane
(C₄) to hexadecane (C₁₆) - Gas chromatographic method
- ISO 6976: 1983 Natural gas - Calculation of calorific value, density
and relative density

Informative reference Attached Table 1.
Calorific value measurement recording Table (An example)
(In the case of expressing the calorific value by kJ/m³ unit)

Sample gas	Measuring place	Measurer	Measurement date time	Year	Month	Day	From hour	min		
No. of calorimeter	No. of gas meter		No. of flowing water thermometer	Inlet	Outlet					
Sample gas temperature in gas meter $t_g =$	℃		Saturation pressure of steam at $t_g =$	S =				kPa		
Room temperature $t_r =$	℃		Temperature of combustion exhaust gas $t_e =$					℃		
Wet-bulb temperature of humidity control type air moistener $t_w =$	℃	Dry bulb temperature $t_d =$	℃	Air humidity for combustion				%		
Pressure of gas meter $P_g =$	kPa		Pressure converted to mercury column $P =$					kPa		
Reading of barometer $B =$	kPa	(℃) Corrected value $\alpha =$	Atmospheric pressure converted to 0℃ temperature $B_0 = B - \alpha =$					kPa		
Correction coefficient of calorimeter $f_1 =$		Correction coefficient of gas meter $f_2 =$		Overall correction factor $f = f_1 \times f_2 =$						
Heating value conversion factor $F_1 = \left(\frac{273.15}{t_g + 273.15} \times \frac{1}{P_g} \right) \times (B_0 + P - S) \times f$										
Amount of sample gas required for measurement of one time $V =$			L	Flow water temperature ℃						
Absolute pressure of dry gas B_0 ----- $+ P$ ----- $- S$ -----				I		II		III		
				Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	
			1							
			2							
			3							
			4							
			5							
			6							
			7							
			8							
9										
10										
Average temperature t_1			℃							
Instrumental error correction value δ			℃							
Exposed part correction value θ			℃							
Corrected temperature $t_1 = t_1 + \delta + \theta$			℃							
Flow-water temperature difference t_2			℃							
Measured mass of water W			g							
Measured calorific value	$H_3 = \frac{W \times t_2}{V} \times F_2$		kJ/m³							
	Mean value $H = \frac{\sum H_i}{n}$		kJ/m³							
Calorific value of 1 m³ dry gas converted to standard condition Total calorific value H_0 kJ/m³ = $\frac{H}{F_1}$										

Remarks: For the calculation of calorific value conversion factor F_1 , single unit system shall be used.
In the case where measured calorific value H_i and total calorific value H_0 are expressed by kcal/m³, these may be not multiplied by F_2 (4.18605).

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Informative reference Attached Table 2.
Calorific value measurement recording table (An example)
(In the case of expressing the calorific value by kcal/m³ unit)

Sample gas	Measuring place	Measurer	Measurement date time	Year	Month	Day	From hour	min
No. of calorimeter	No. of gas meter		No. of flowing water thermometer	Inlet	Outlet			
Sample gas temperature in gas meter t_g	°C	Saturation pressure of steam at t_g	mmHg					
Room temperature t_r	°C	Temperature of combustion exhaust gas t_e	°C					
Wet-bulb temperature of humidity control type air moistener t_w	°C	Dry bulb temperature thereof t_d	°C	Air humidity for combustion	%			
Pressure of gas meter P_g	mmH ₂ O	Pressure converted to mercury column P	mmHg					
Reading of barometer B	mmHg	(°C) Corrected value a	Atmospheric pressure converted to 0°C temperature $B_0 = B - a$ mmHg					
Correction coefficient of calorimeter f_1	Correction coefficient of gas meter f_2	Overall correction factor $f = f_1 \times f_2$						
Heating value conversion factor $F_1 = \left(\frac{273.15}{t_g + 273.15} \times \frac{1}{P_g} \right) \times (B_0 + P - S) \times f =$								
Amount of sample gas required for measurement of one time $V =$			L					
Absolute pressure of dry gas			Flow water temperature °C					
			I		II		III	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
			1					
			2					
			3					
			4					
			5					
			6					
			7					
8								
9								
10								
Average temperature t_i			°C					
Instrumental error correction value δ			°C					
Exposed part correction value θ			°C					
Corrected temperature $t_i = t_i + \delta + \theta$			°C					
Flow-water temperature difference t_w			°C					
Measured mass of water W			g					
Measured calorific value	$H_j = \frac{W \times t_d}{V}$		kcal/m ³					
	Mean value $H = \frac{\sum H_j}{n}$		kcal/m ³					
Calorific value of 1 m ³ dry gas converted to standard condition Total calorific value H_0 kcal/m ³ = $\frac{H}{F_1} =$								

Remarks: For the calculation of calorific value conversion factor F_1 , single unit system shall be used.

Informative reference Attached Table 3.
Calculation table of calorimetric values and specific
gravities of gases (An example)
(In the case of expressing the calorific value by kJ/m^3 unit)

Test year, month and day _____

Sample test _____

No.	Component	Molecular formula	Total calorific value in ideal condition H_i	Specific gravity in ideal condition S_i	Compression addition coefficient $\sqrt{b_i}$	Component mol content rate C_{Mi}	Calculation compression addition coefficient $C_{Mi}\sqrt{b_i}$	Calculation calorific value $C_{Mi}H_i$	Calculation specific gravity $C_{Mi}S_i$
1	Hydrogen	H_2	12 790	0.069 6	—		—		
2	Oxygen	O_2	—	1.104	0.031 6			—	
3	Nitrogen	N_2	—	0.967	0.022 4			—	
4	Carbon monoxide	CO	12 600	0.967	0.024 5				
5	Carbon dioxide	CO_2	—	1.519	0.067 0			—	
6	Methane	CH_4	39 840	0.554	0.050 0				
7	Ethane	C_2H_6	69 790	1.038	0.098 5				
8	Ethylene	C_2H_4	63 060	0.968	0.088 3				
9	Propane	C_3H_8	99 220	1.522	0.145 9				
10	Propylene	C_3H_6	91 960	1.452	0.137 5				
11	Butane	C_4H_{10}	128 600	2.006	0.205 7				
12	Isobutane	C_4H_{10}	128 200	2.006	0.190 8				
13	1-Butene	C_4H_8	121 400	1.936	0.190 8				
14	Cis-2-butene	C_4H_8	121 100	1.936	0.208 6				
15	Trans-2-butene	C_4H_8	120 900	1.936	0.205 4				
16	Isobutene	C_4H_8	120 700	1.936	0.196 2				
17	1,3-Butadiene	C_4H_6	113 500	1.866	0.186 3				
18	Pentane	C_5H_{12}	158 100	2.490	0.279 3				
19	Isopentane	C_5H_{12}	157 700	2.490	0.261 7				
20	Neopentane	C_5H_{12}	157 100	2.490	0.231 7				
21	1-Pentene	C_5H_{10}	150 800	2.420	0.261 2				
22	Cis-2-pentene	C_5H_{10}	150 600	2.420	0.265 1				
23	Trans-2-pentene	C_5H_{10}	150 400	2.420	0.265 1				
24	2-Methyl-1-butene	C_5H_{10}	150 200	2.420	0.254 0				
25	3-Methyl-1-butene	C_5H_{10}	150 500	2.420	0.242 9				
26	2-Methyl-2-butene	C_5H_{10}	150 000	2.420	0.256 5				
27	Cyclopentane	C_5H_{10}	148 400	2.420	0.260 6				
28	Hexane	C_6H_{14}	187 500	2.974	0.361 5				
29	Isohexane	C_6H_{14}	187 200	2.974	0.351 9				
30	3-Methyl pentane	C_6H_{14}	187 300	2.974	0.323 6				
31	2,2-Dimethyl butane	C_6H_{14}	186 700	2.974	0.340 0				
32	2,3-Dimethyl butane	C_6H_{14}	187 100	2.974	0.350 9				
33	Benzene	C_6H_6	147 500	2.695	0.311 6				
34	Toluene	C_7H_8	176 400	3.179	0.475 5				
Sum			—	—	—				

Compression coefficient of sample gas

$$Z = 1 - (\sum C_{Mi}\sqrt{b_i})^2 + 0.000\ 5(2C_{MH} - C_{MH}^2) =$$

Calculation calorific value of sample gas (kJ/m^3)

$$H_G = \frac{\sum (C_{Mi}H_i)}{Z} =$$

Calculation specific gravity of sample gas

$$S = \frac{\sum (C_{Mi}S_i)}{Z} =$$

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